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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 847

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER August 9, 1920

ROUNDHEADED APPLE-TREE BORER:

ITS LIFE HISTORY AND CONTROL

By

FRED E. BROOKS, Entomologist,
Deciduous Fruit Insect Investigations

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By Fred E. Brooks, *Entomologist, Deciduous Fruit Insect Investigations.*

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INTRODUCTION.

In the spring of 1911 a field station of the Bureau of Entomology was established at French Creek, W. Va., and a study begun of the roundheaded apple-tree borer in connection with a general project on boring insects attacking deciduous fruit trees. The work was under the direction of Dr. A. L. Quaintance and was placed in charge of the writer, with whom was associated, in 1911 and 1912, E. B. Blakeslee, of the Bureau of Entomology. During the summers of 1915, 1916, and 1917 C. R. Cutright was employed temporarily to assist with the investigation.

The field station is located in a hilly, partly wooded region where small orchards, wild seedling apple trees, and native host trees of the borer abound and where the insect itself is plentiful. For rearing purposes and the testing of control measures, 1,000 3-year-old apple trees, of the varieties known as King, Grimes, and York Imperial, were planted in the adjacent locality of Elkins, W. Va., on land leased for the purpose. In addition to the work at the two points mentioned, rearing and life-history studies were conducted at Pickens, Weston, and Great Cacapon, W. Va., and at Demorest, Ga.,

[1] *Saperda candida* Fabr.; order Coleoptera, family Cerambycidae.

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Biltmore, N. C., Winthrop, Me., and Munising, Mich. First-hand observations on the species were made also in many other localities and more or less original data obtained therefrom. The studies were continued over the period 1911 to 1918.

HISTORY.

The roundheaded apple-tree borer was first described by J. C. Fabricius in 1787 (1)[1] as *Saperda candida*. In 1824 it was redescribed by Thomas Say (2) as *Saperda bivittata*, and by this name it was commonly referred to by Harris, Fitch, Walsh, and other early American writers on economic entomology. From 1875 to 1885 Riley, Lintner, and others recognized the priority of Fabricius's name, and since that time the species has been rightfully designated *Saperda candida*.

The insect is native to North America and originally fed upon and bred within a limited number of forest trees and shrubs belonging to the family Rosaceae. When cultivated orchards of apple, pear, and quince began to be established in the eastern part of the United States the borer soon found its way from the forests into the orchards and did much damage to valuable fruit trees. There are many records of serious injury in New York and throughout the New England States, beginning as early as 1825. Apple trees seem to have suffered most; in some cases entire orchards were destroyed, and the loss of 50 per cent of the trees was not unusual. Felt and Joutel (6) cite numerous historical references showing the widespread and destructive nature of the insect in the days of pioneer orcharding in this country. In more recent times, as the orcharding interests of the country have developed, losses from this insect have increased rather than diminished. At the present time it is an orchard pest of primary importance throughout a great portion of the apple-growing region east of the Rocky Mountains.

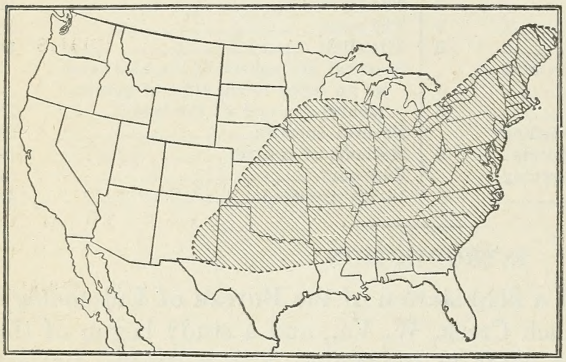


FIG. 1.—Distribution of the roundheaded apple-tree borer (*Saperda candida*).

DISTRIBUTION.

The known range of the roundheaded apple-tree borer may be bounded by a line extending from near the mouth of the St. Law-

[1] Numbers in parenthesis refer to "Literature cited," p. 41.

rence River westward through Quebec and Ontario to Minnesota, thence in a southwesterly direction through Nebraska, Kansas, and New Mexico to Texas, and thence eastward through Texas, Louisiana, Mississippi, Alabama, and Georgia to the Atlantic coast. (See fig. 1.) There seem to be no data showing that the general range of the species has been greatly extended by the development of the orchard industry of the country.

Within the bounds of its range there are many limited districts where the borer does not occur, or, at least, where it is very uncommon. Just why this is true can not be fully explained, but the absence of native host trees and the abundance of those species of woodpecker which prey upon the borers are two factors which often have much to do with the local scarcity of the pest. Areas of comparative freedom and corresponding areas that are heavily infested often exist near together for years at a time with little relative change. This occurs in native woods as well as in orchards. The peculiarity may be partly explained by the tendency of the species to colonize or form family breeding centers, far from which the adult females do not habitually wander.

FOOD PLANTS.

Probably no other tree is so subject to attack by this borer as the quince. Wherever the borer is common it is difficult to succeed with this fruit. Quince trees are usually small and one or two borers can injure greatly or kill a tree in a single year. The habit which the quince has of sending up suckers or sprouts around the central stem tends to give the borers a good chance to work. In the bases of such clumps borers are hard to reach in the worming process and there they may find positions where woodpeckers can not get at them. Apple is undoubtedly the second choice, and probably mountain ash (*Sorbus americana*) is next in favor. Of the cultivated fruits, quince, apple, and pear are preferred in the order named. Mountain ash, service (*Amelanchier canadensis*), wild crab (*Pyrus* spp.), hawthorn (*Crataegus* spp.), and chokeberry (*Aronia* spp.) are native hosts which are attacked about in the order stated. There are records in the Bureau of Entomology of the development of this borer in peach, but it is certain that this tree is very rarely attacked.

In one instance in West Virginia all the host trees of this borer which grew on a certain tract of woodland and grown-up field were cut and examined to determine the relative extent of infestation of each species of tree. The trees examined numbered 1,483 and the results of the count are given in Table I. It is probable that in any adjacent locality a considerable variation from these figures might have been found, yet the results of the count showed what is ap-

parently a constant preference for apple over the other species of host trees present in this instance.

TABLE I.—*Relative numbers of roundheaded apple-tree borers found in different species of host trees at French Creek, W. Va.*

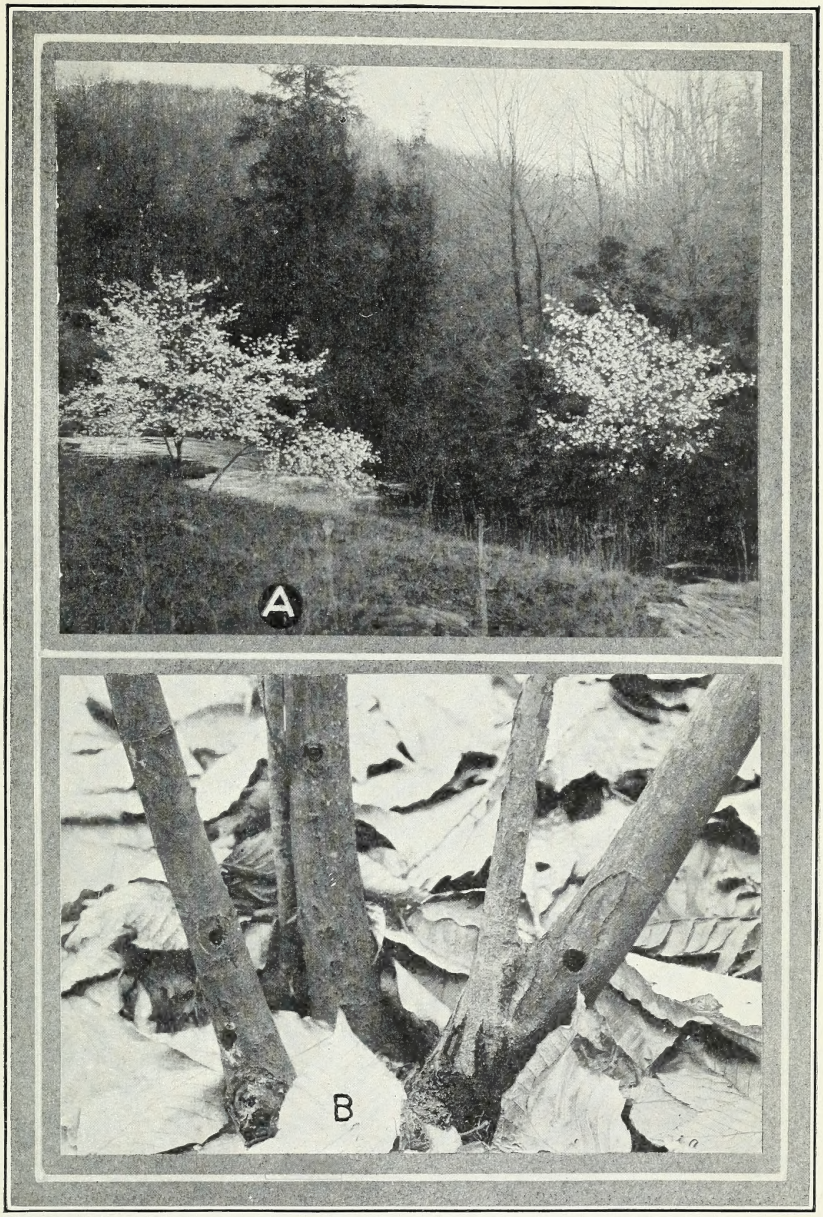
Trees examined.		Number of borers.
Number.	Variety.	
194	Seedling apple	85
11	Pear	0
823	Wild crab	9
405	Hawthorn (Crataegus)	1
50	Service	0
1,483	Total	95

It will be noted from Table I that in this case the 50 service trees (Pl. I) examined contained no borers. This is far from the rule as regards the service, for in woods where that tree and mountain ash abound tracts are often found where practically every tree is infested. (Pl. I, B.) Other areas near by of equal size are quite likely to occur where no borers can be found, although the host trees may be just as abundant as where infestation is general. This arises from the fact that under natural conditions families or communities become established and reproduce through many generations within restricted areas. It is probable that adult males fly readily from one breeding center to another, preventing thereby an excess of interbreeding, but the females do not normally tend to go far from the tree in which they developed, provided other host trees are near. This tendency for infestation to be confined to limited groups of trees is often noted in cultivated orchards. Isolated trees are sometimes attacked, however, and there is no question that the female is capable of flying to a considerable distance when impelled by a scarcity of trees in which to oviposit.

DISTRIBUTION AS AFFECTED BY NATIVE HOST PLANTS.

As has been pointed out, the principal native host trees of the roundheaded apple-tree borer are the service, mountain ash, wild crab apple, and hawthorn. Of these wild hosts service and mountain ash seem to be preferred to the others. It is an interesting fact that the service tree (Pl. I, A) occurs over practically the same region of North America as does the insect in question.

These wild food plants undoubtedly play an important part in the local and general distribution of the borer. Infestations commonly attributed by orchardists to certain soil conditions, to newly cleared land, or to the hilly contour of the land are in reality usually due to



ROUNDHEADED APPLE-TREE BORER.

A, Blooming service trees, *Amelanchier canadensis*. At this season of the year borers are undergoing transformation to beetles. B, Exit holes of beetles in clump of young service trees.

ROUNDHEADED APPLE-TREE BORER.

Wire-screen cages used on infested apple trees to hold escaping beetles.

the proximity of the insect's breeding places, the breeding places quite often consisting of these wild host trees that thrive on account of favorable soil, elevation, or other local conditions. Orchards established on newly cleared lands and in hilly locations are more likely to have woods or neglected thickets of wild crab apple, seedling apple, or hawthorn growing near to them than are orchards in the more valuable and highly cultivated valley or level lands. The wild host trees that grow in the woods and thickets (Pl. I) are usually breeding places for the borer, and the adult insects that develop within them fly to the orchards near by and deposit their eggs. In some localities of the Shenandoah apple region the idea is prevalent that borers discriminate between soils and prefer the shale lands of the hills rather than the clay and loam of the valleys. The greater abundance of borers in hill orchards, however, can be explained by the prevalance in such localities of the wild trees in which they breed (Pl. VII, C), the soil having only the indirect bearing on the situation that the shale lands favor the growth of service and other wild host trees.

The native service tree (Pl. I) is perhaps the most effective distributor of this insect. In about 25 localities within the States of Maine, Michigan, Pennsylvania, West Virginia, Virginia, North Carolina, Georgia, Alabama, Mississippi, and Florida, where careful investigations were made, the absence, scarcity, or abundance of service trees was accompanied by a corresponding absence, scarcity, or abundance of the roundheaded apple-tree borer.

CHARACTER OF INJURY.

About 95 per cent of the eggs (Pl. IV, B, C, E) of this borer are deposited within the bark at the base of the tree trunk. (Pl. III.) Usually the eggs are within 6 inches of the ground, but occasionally they are placed in a crotch of the tree or even in a branch 10 or 15 feet above ground. The larva (Pl. V, A, B; VIII, A), which hatches in early summer, feeds at first on the inner bark, eating out a roughly circular space about the oviposition scar and ejecting stringy, sawdustlike castings of a reddish color through small openings in the outer bark. (Pl. V, C.) As the larva develops it extends its gallery either up or down the tree or transversely with the grain of the bark and before the end of the first season may burrow into the wood. (Pl. V, A, B.) More frequently, however, it spends the first winter in the inner bark and enters the wood the second summer. The burrows, both in the bark and wood, are broad and irregular in form, and, with the exception of a space about the borer (Pl. VI, D), are packed with digested wood particles (Pl. VII, A, C). The borer feeds from about the blooming time of apple in the spring until late

in the autumn and continues to throw out castings until it begins the construction of its pupal quarters. (Pl. VII, A.)

Trees of all ages are attacked, but the most severe injury is done to young trees, in which the wound made is greater in proportion to the size of the trunk. (Pl. IV, D.) Frequently a number of borers will attack a single tree and girdle it completely or so riddle and weaken the heartwood that the tree will break over at the surface of the ground. It is not unusual to find a dozen borers in one tree, and on one occasion the writer found 25 within an 8-year-old apple tree. Felt and Joutel (6) cite an instance where 30 borers were removed from one tree.

Trees severely injured by borers present a sickly appearance, the foliage being sparse and of a pale green color. (Pl. VI, A.) When of bearing age they are inclined to bloom freely and set heavy crops of fruit, the fruit developing poorly and the trees often dying in an effort to bring the crop to maturity. If any part of an orchard is bounded by woods the first and most severe injury usually occurs among trees near to such woods.

METHODS USED IN SECURING BREEDING MATERIAL AND REARING THE INSECTS.

In the rearing work connected with this investigation many individual insects were carried through from eggs to adults in young apple trees planted for the purpose. Larger apple trees were used in which to plant newly hatched borers for rearing purposes. The trunks of some trees were made to support and bring to maturity as many as 25 borers. Each spring a large number of pupæ were secured by scouring the roadsides, grown-up fields, and neglected orchards of various localities for small, worthless seedling-apple trees in which the insects were maturing. Such trees were cut near the ground and short sections of the base of the trunk containing the pupæ sawn off and taken to the insectary, where they were kept in rearing cages. Many pupæ were also chiseled out of trees and placed in small glass vials excluded from the light. About 75 per cent of the pupæ kept in the vials developed into normal adults.

CAGES USED FOR REARING AND OBSERVING BORERS.

In carrying on the work herein described three types of fine-meshed, wire-screen cages were used. The first were small cylinders fitted around the bases of trees in which borers were developing (Pl. II). These cages were about 15 inches in length, the lower end when in place being sunk in the earth for half an inch and the space at the top between the wire and tree packed with cotton batting. Such cages excluded woodpeckers, imprisoned emerging beetles, and

were useful in other ways in preventing the disturbance of the insects. A larger form of cage was made by stretching wire over a light wooden frame 2 by 2 by 4 feet in dimensions. Cages of this type were used to set over apple trees 3, 4, or 5 years of age that had been headed low and pruned in for the purpose. When in place these cages were mounded slightly with earth at the bottom to prevent the escape of the beetles and were secured from wind by being attached with screws to posts driven into the ground at the corners. In these cages many beetles were confined over growing trees, and, so far as could be observed, lived lives comparable in length with those in the field. Several other cages of larger size were built over clumps or short rows of young apple trees. Some of these cages were 20 feet in length by 8 feet wide and 8 feet high. They were provided with tight-fitting doors large enough to admit a man and were used for observations on the various stages of the borer and for testing control measures.

THE EGG AND OVIPOSITION.

THE EGG.

The egg (Pl. IV, B, C, E) when first deposited is yellowish white, assuming a darker shade within a few days. It is 3.5 to 4 mm. in length by 1 to 1.5 mm. in width, slightly flattened, both ends tapering to rounded points, the shell tough and plastic, bending somewhat in conformity to the space which it occupies. There is considerable variation in size and shape.

THE OVIPOSITION PROCESS.

Egg laying usually begins a week or ten days after the female beetles leave the wood. In preparing to oviposit, the female assumes an oblique position on the bark (Pl. III, A) and with her jaws makes a slightly curved slit in the bark 4 or 5 mm. in length, and usually extending parallel with the grain of the bark. (Pl. IV, A.) After the incision is completed, the beetle turns, inserts the tip of the ovipositor into the opening, and with considerable effort forces it into the tissue, usually between the bark and wood. (Pl. IV, B, C.) The ovipositor is inserted at about the center of the slit made with the mandibles and is extended under the bark in a direction at right angles to the slit. The egg is placed with the end toward the slit and from 1 to 2 mm. from it at the nearest point. After the ovipositor is withdrawn a small mass of clear, gelatinous liquid is ejected into the hole, which dries and seals the egg chamber. Two or three minutes are spent in making the initial slit and twice that time in inserting the ovipositor, laying the egg, and sealing the

opening. Several eggs are usually deposited at a time within one tree (Pl. IV), quite often the second slit in the bark being made joining and in line with the first. When the bark over eggs is peeled off the eggs adhere to the bark rather than to the wood. (Pl. IV, B, C.)

After the batch of eggs is deposited the beetle may crawl up the trunk to the branches or may move away on the ground for a little distance and then take wing.

TIME OF DAY DURING WHICH EGGS ARE LAID.

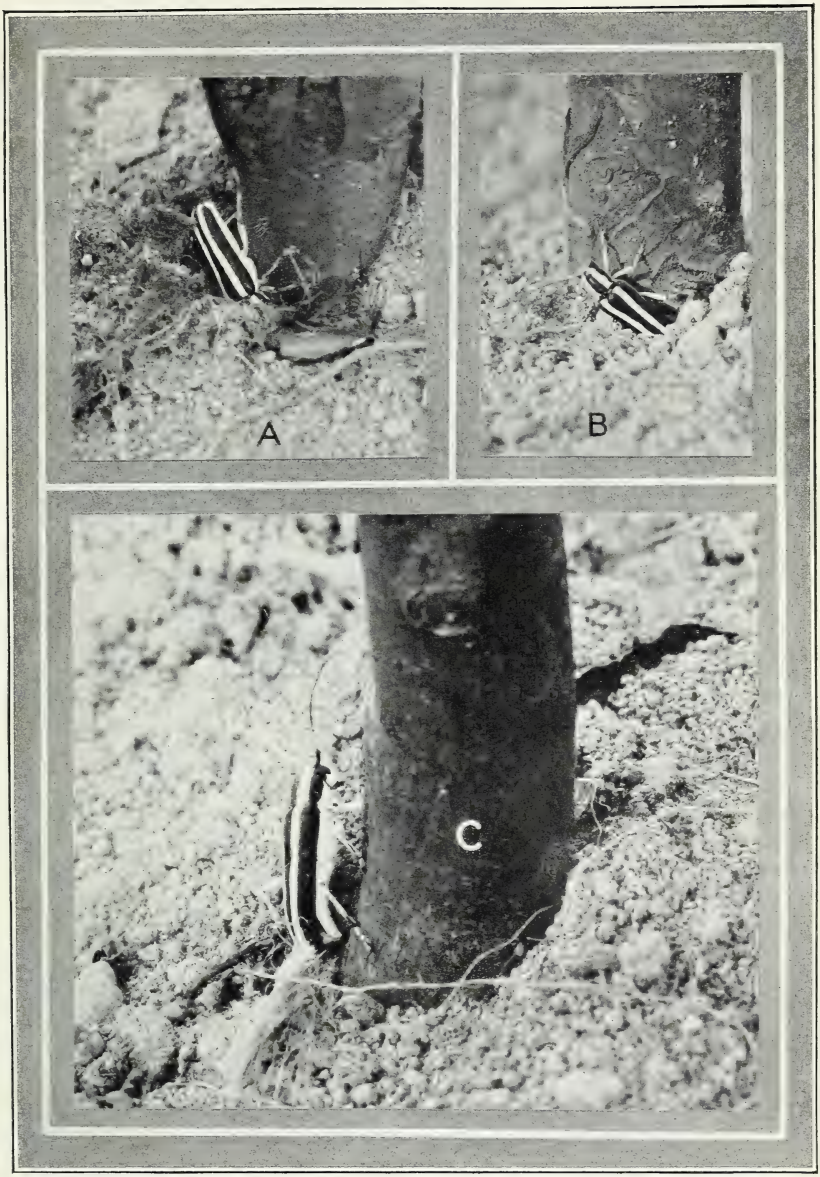
Most of the eggs are deposited during the hotter part of warm, sunny days. No evidence was obtained that oviposition ever takes place at night. In one case a female was found ovipositing at 5.30 a. m. and others were several times observed laying eggs near twilight in the evening, a time of special activity with both sexes of beetles.

PLACE OF OVIPOSITION.

As has been stated on another page, probably 95 per cent of the eggs of the roundheaded apple-tree borer are deposited in the trunks of trees within 6 inches of the ground; usually they are not more than 1 or 2 inches above the soil and quite often they are on a level with (Pl. III, C) or slightly below the surface. (Pl. III, A, B.) In rare instances eggs are deposited in the crotches of trees, around the edges of cavities in the trunk or larger branches, and even in small branches high up in the trees. In one case the writer found two larvæ working in a branch 15 feet above the ground. Usually woodpeckers remove the borers that begin operations aloft in the trees. Possibly the beetle's habit of ovipositing close to the ground has evolved from the greater dangers attendant upon the higher locations.

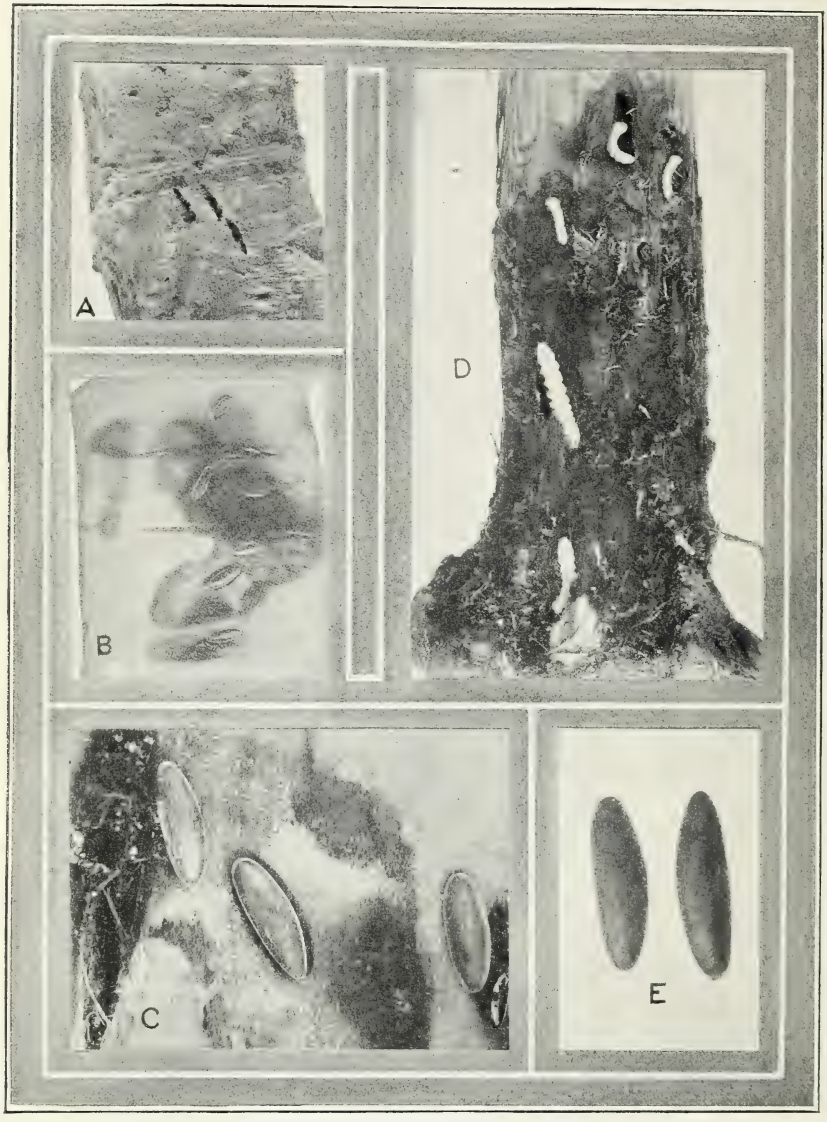
When the female beetle is ready to oviposit she usually crawls from among the branches downward along the trunk. In descending, if an obstacle of any kind is encountered she may pause and oviposit in the bark above it. This habit accounts for borers occasionally found in the crotches of trees. The writer found numerous eggs and larvæ above burlap bands which had been placed around the trunks of apple trees for trapping codling moth larvæ. When similar bands were placed on trees in cages the beetles laid more eggs above the bands than at the ground. In one test of this kind, comprising 5 trees and 5 female beetles, 36 eggs were laid above the bands and only 15 at the ground below the bands. These bands were attached around the trunks about 15 inches up from the ground.

The statement has been made that the females prefer to oviposit in the trunks of trees that are surrounded and shaded by weeds,



ROUNDHEADED APPLE-TREE BORER.

A, Female beetle splitting the bark of a young apple tree just below the surface of the ground preparatory to depositing an egg. Natural size. B, Female beetle placing an egg in the tree just below the surface of the ground. Natural size. C, Female beetle ovipositing at the surface of the ground. Slightly enlarged.



ROUNDHEADED APPLE-TREE BORER.

A, Oviposition scars in bark of young apple tree. Natural size. B, Inner surface of bark peeled from young apple tree, showing position of eggs. Natural size. C, Eggs in natural position. Much enlarged. D, Young borers attacking lower trunk of young apple tree. E, Eggs. Much enlarged.

litter, or water sprouts, and that trees so surrounded are more likely to be injured by borers than those having trunks exposed to the full light. Observations made by the writer, however, indicate that the beetles prefer to oviposit in the sunlight rather than in the shade. In one case 609 borers were removed from an orchard of 6-year-old apple trees which was located on a hillside having a general slope to the southwest. The trunks of the trees were long and one side received the unobstructed sunlight during a greater part of the day. The oviposition scars in which the borers hatched were found and those situated on the sunny side and shady side of the trunks were counted separately. As nearly as possible, each side was made to include half the circumference of the trunk. Of the 609 oviposition scars which were located, 393 were on the sunny or exposed side and 216 on the shaded side. The fact that about 65 per cent of the eggs had been laid on the more exposed side of the trees indicates that mulches of straw or hay placed around trees or the shading of the trunks by low branches does not attract the beetles, but rather repels them.

OVIPOSITION IN CAGES.

Other workers with this insect seem to have had but little trouble in inducing caged female beetles to oviposit in apple twigs, in sections of apple branches set in the ground, and even in apple fruits. The writer, however, has never been able to get a normal frequency of oviposition in any but growing trees. At one time 15 pairs of beetles were confined separately in roomy cages for a period of 17 days. Fresh apple branches, about an inch in diameter, were set in the ground daily in each cage. Although this was kept up from May 31 to June 17, a time when egg laying in the field was at its height, only 17 eggs were secured in the branches and 10 of the 15 females failed altogether to oviposit. The cages with the beetles were then removed and placed over small growing apple trees, whereupon oviposition began freely and at once. Attempts to induce caged females to oviposit in other than growing trees were made frequently, but never with entire success.

OVIPOSITION PERIOD.

As an example of the period of time over which eggs are deposited in a given locality, observations made in 1914 may be cited. During that year the first female issued on May 23. Eight days later she paired with a male and on June 4 laid her first eggs. No record was obtained of the last egg of this individual but other females continued to oviposit until August 1, the entire egg-laying

period for the year covering 58 days. It is not unusual to find unhatched eggs in the field in the latitude of West Virginia from August 10 to 15, although none have been found after August 15. From these and from considerable other data obtained, it appears that normally egg laying continues in a given locality from 50 to 60 days, although perhaps no single individual oviposits over so long a period of time.

INDIVIDUAL EGG CAPACITY.

The number of eggs normally deposited by a single female beetle is not great, the average number having been found by different investigators to vary considerably. Felt and Joutel (6) mention 10 as being about the quota for one individual, while Becker (14), making observations in the Ozark Mountain regions, found the number to range from 16 to 93, with an average of 40.8 per female for five individuals. The writer obtained egg counts from 15 individuals, the figures being shown in Table II.

TABLE II.—*Individual egg capacity of female beetles of the roundheaded appletree borer at French Creek, W. Va.*

Year.	Number of females.	Number of eggs.	Average number of eggs per female.
1911	3	52	17.3
1914	1	17	17
1914	1	20	20
1914	1	22	22
1912	1	13	13
1912	1	20	20
1914	7	193	27.6
Total	15	337	.....
Average number of eggs per beetle			22.5

Table II shows that the minimum and maximum numbers of eggs obtained from 15 beetles were 13 and 27.6, the average being 22.5. Since these records were obtained in several different years under conditions that were approximately normal they probably represent fairly accurately the average number of eggs laid by females in the locality mentioned.

PERIOD OF INCUBATION OF EGGS.

The time required for the eggs to hatch has been variously stated at from 8 days to 3 weeks. The writer noted the period in 8 instances, the data for which are set forth in Table III.

TABLE III.—*Period of incubation of the roundheaded apple-tree borer at French Creek, W. Va.*

Dates on which eggs were laid.	Dates on which eggs hatched.	Number of eggs.	Number of days required to hatch.
June 14	June 28	1	14
June 12	do	1	16
June 9	June 25	1	16
Do	June 26	1	17
June 10	June 23	1	13
June 13	June 29	1	16
Do	June 30	1	17
Do	July 2	1	19
Average period of incubation			16 days.

As is shown in Table III, the minimum and maximum periods of incubation were 13 and 19 days, the average for the 8 eggs being 16 days. Evidence was obtained that hatching is retarded by low and accelerated by high temperatures.

THE LARVA.

The larva (Pl. V, A, B) is a cream-colored, footless grub, with brown head, blackish mandibles and a conspicuous patch of small, brown tubercles on the posterior half of the broad, flattened dorsal surface of the first thoracic segment. The intersegmental constrictions are deep and the dorsal and ventral surfaces of the first seven abdominal segments are elevated and roughened. The sides of the body are sparsely covered with short, stiff hairs. When full grown, the length is from 30 to 40 mm., the females being considerably larger than the males. According to Becker (14) there may be as many as six larval instars.

DEVELOPMENT AND FEEDING HABITS OF THE LARVA.

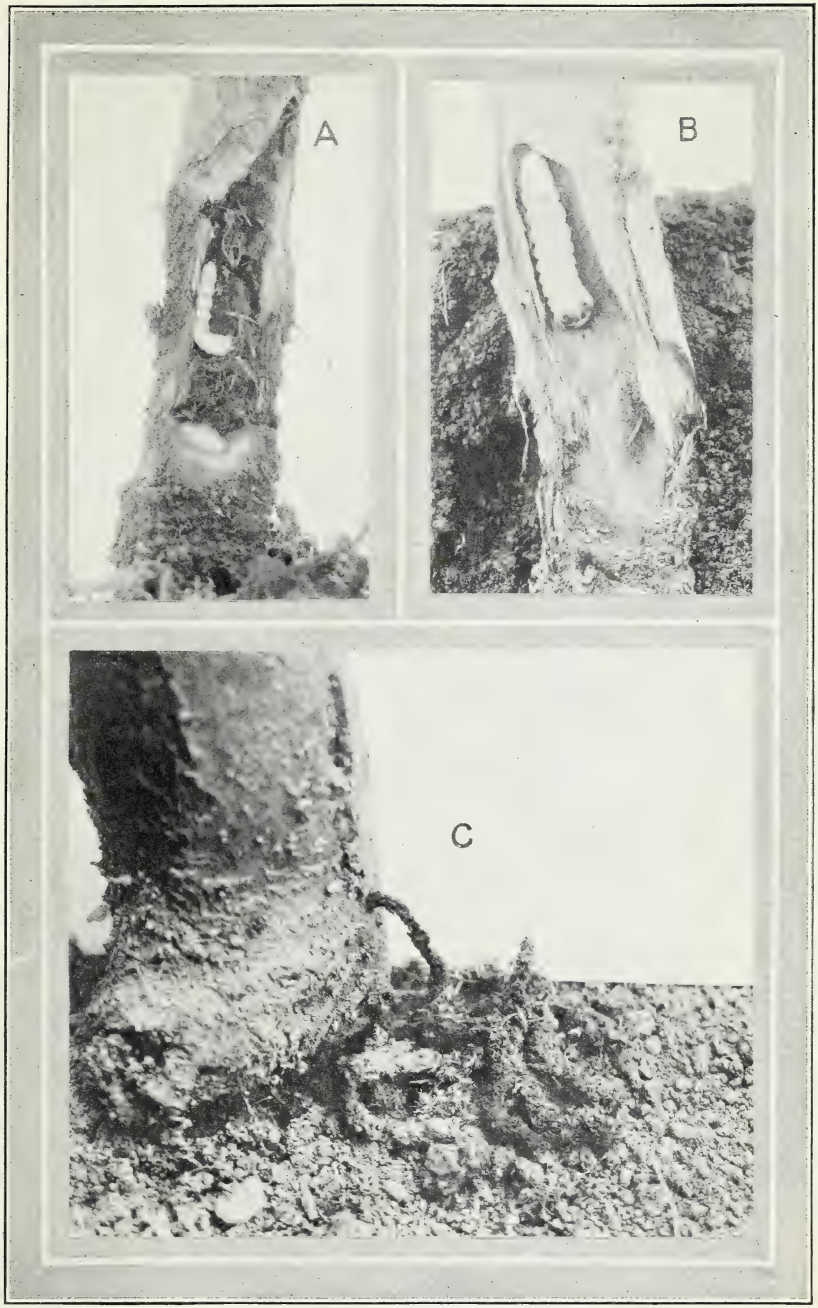
The behavior of the larva varies as affected by individual characteristics, difference in size, vigor, and species of host trees, and difference in localities, so that no one description of the larval development will apply to all. In the latitude of West Virginia the activities and growth of the larva when feeding under normal conditions in apple are about as follows: The larva begins to feed at once after leaving the egg and soon eats out a broad, irregular, usually more or less circular burrow around the point where the egg was laid. At this stage of its life growth is rapid and the borer soon forms a broad, elongate gallery under the bark which may extend in any direction away from the point first attacked. As winter approaches there is some tendency to burrow downward to or beneath the soil, but this is by no means general.

At first the feeding is all in the bark and the point of injury usually shows from the outside as a dark, slightly depressed spot from

which castings are ejected and from which a small quantity of sap often flows. In some cases the borer burrows into the wood the first season, but usually it does not enter the wood until the succeeding spring. In small trees the galleries penetrate to the heart, but in old trees they are seldom extended more than an inch beneath the inner bark. The burrows in the wood, like those in the bark, are broad and irregular in shape and usually extend both above and below the surface of the ground. In the northern part of the insect's range a greater proportion of the feeding seems to take place beneath the ground. The writer found larvæ in Maine burrowing downward in the roots to a distance of a foot or more from the base of the trunk, a depth which does not seem to be reached in the South. Many 1-year-old larvæ were also found in Maine that had not yet penetrated into the wood but were still feeding in the bark near the old oviposition scars. In all their feeding larvæ keep an open space about themselves, to allow of free movement, but pack the balance of their burrows with wood fragments. Strings of reddish-brown castings are also thrown out from the tree through small openings in the bark. (Pl. V, C.)

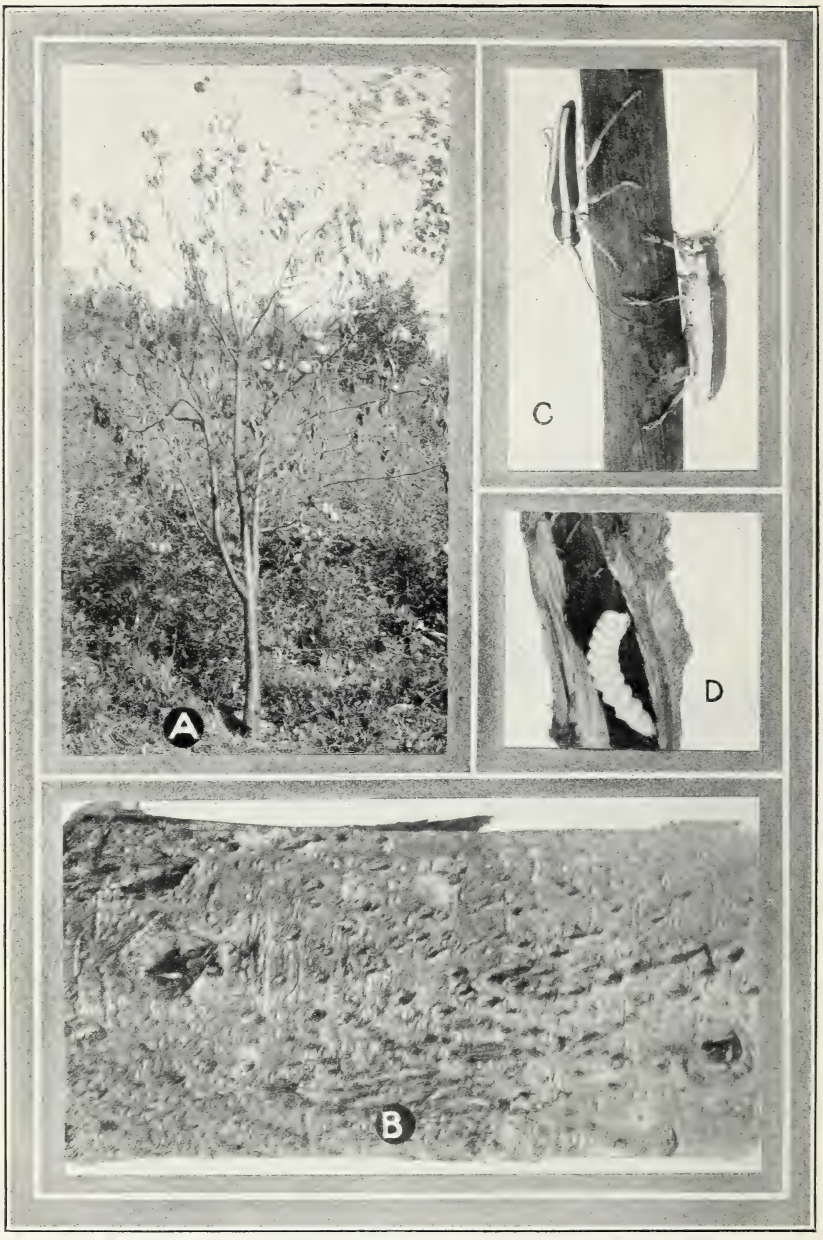
In the late summer and autumn preceding the spring during which pupation is to take place, the larvæ excavate galleries leading up the trunk of the tree a short distance beneath the bark. (Pl. VIII, A, B.) At the upper end of this gallery the pupal chamber is formed by slightly enlarging the circumference of the opening and curving the upper end outward to the inner bark. (Pl. VII, A.) The curved upper end is packed lightly with wood dust and a considerable space in the gallery below the pupal chamber is filled with short, excelsior-like strings of wood torn from the walls of the opening. (Pl. VIII, A.) The space for the pupa is often 2 inches or more in length and both the larvæ and pupæ when occupying it recede or advance when disturbed, evidently a provision for escaping woodpeckers. The pupal quarters usually are practically completed in the autumn but the larvæ add finishing touches in the spring before they pupate. In small trees the exit holes at the upper end of the pupal chambers are usually within from 4 to 8 inches of the ground, but in large trees it is not unusual to find the place of exit at the terminus of a gallery extending upward from the ground to a distance of 18 inches or 2 feet. Just why the pupal quarters should be made higher in large trees than in small trees does not seem to have been determined.

Wintering larvæ begin activities early in the spring and continue to feed until stopped by the cold weather of winter. Probably the annual feeding period in the South is much longer than in the North.



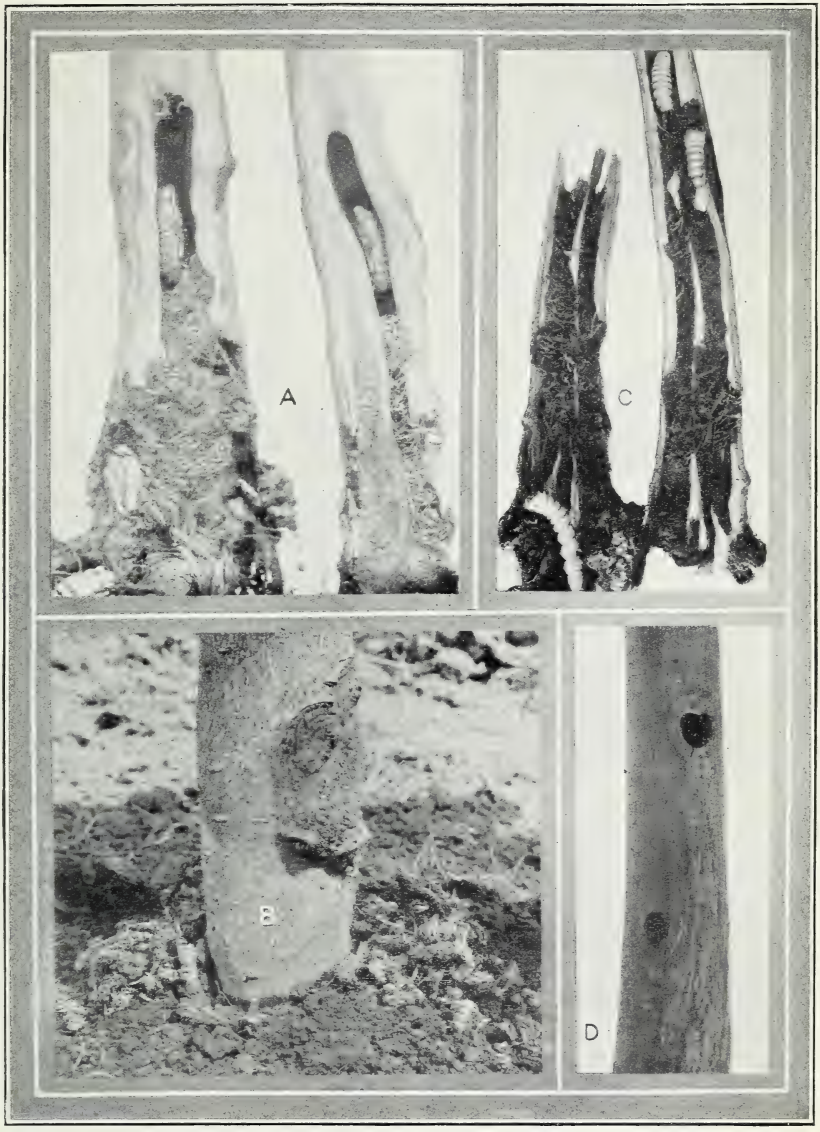
ROUNDHEADED APPLE-TREE BORER.

A, Borer, first summer in tree. Natural size. B, Second summer in tree. Natural size. C, Castings being ejected from tree by borer.



ROUNDHEADED APPLE-TREE BORER.

A, Young apple tree dying from injuries caused by roundheaded apple-tree borers. B, Trunk of young apple tree marked by beak of woodpeckers searching for borers; the larger wounds show where borers have been removed. C, Adult roundheaded apple-tree borers; male above and female below. Slightly enlarged. D, Borer in apple tree; showing cleared space maintained in burrow to allow of free movement of body. Natural size.



ROUNDHEADED APPLE-TREE BORER.

A, Pupæ in natural position in tree. B, Castings of borers at base of young apple tree. C, Borers in young service tree. D, Exit holes of beetles.

ROUNDHEADED APPLE-TREE BORER.

A, Larvæ within pupal chambers in young apple tree. Natural size. B, Cross section of base of trunk of young apple tree, showing galleries made by borers in ascending the trunk to pupate. Natural size. C, Beetle resting by exit hole. Natural size.

FORM OF BURROWS IN PEAR DIFFERS FROM THAT IN APPLE.

It was frequently noted that the borers in pear trees formed differently shaped burrows from those made in apple. In pear the burrow is much more elongate, often being a slender gallery 6 or 8 inches in length and extending around the trunk, sometimes almost or entirely encircling trees several inches in diameter. As the larvæ in pear near maturity they enter the wood and pupate much as in apple.

PERIOD SPENT BY LARVA IN THE TREE.

Ever since the roundheaded apple-tree borer began to attract the attention of entomologists there has been some disagreement as to the number of years spent by the larva in the tree. Practically all writers have agreed that the life cycle requires either two or three years for completion. Most of the well-known textbooks on general entomology, as well as the systematic treatise on this particular species, give three years as the life period. Comstock (4, p. 573) says "It requires nearly three years for this larva to attain its growth." Smith (5, p. 209–210), speaking of the larva, says "In the spring of the third year [it] changes to a beetle." Felt and Joutel (6) give a three-year period in the tree. Saunders (8) says "It is generally conceded that the larva is three years in reaching maturity." Sanderson (12) says "The third spring the larvæ transform to pupæ." Slingerland and Crosby (13) state, "It is generally believed that it requires three years for this apple-borer to complete its life cycle." Lutz (15, p. 359) says, "From egg to adult takes three years." Chittenden (7) gives a three-year life cycle. O'Kane (11) says "The larva requires three years for maturity." Both Smith (10, p. 52–54) and Patch (9) give a three-year larval period. Becker (14) says "*Saperda candida* has a two-year life cycle in the Ozarks," but points out that "There seems to be some indication that occasionally a larva may require three years for its development."

The present investigation has shown that the length of the life cycle averages longer in the North than in the South and also that this period may vary several years in length in a given locality. Table IV shows the years required for 121 insects to reach maturity at French Creek, W. Va.

TABLE IV.—*Period of life cycle of the roundheaded apple-tree borer at French Creek, W. Va.*

Year beetles issued.	Number years in tree.				
	1	2	3	4	5
1913	0	9	0	0	0
1914	0	11	2	0	0
1915	2	7	1	0	0
1916	0	36	10	1	0
1917	0	40	2	0	0
Total	2	103	15	1	0
Per cent	1.7	85.1	12.4	0.8	

Table IV shows that out of 121 individuals, 2 issued from the wood as beetles the next year after the eggs were deposited, 103 issued in two years, 15 in three years, and 1 in four years.

Records of the exact number of days elapsing from the deposition of the eggs to the issuing of the beetles were ascertained in a number of instances. These records are shown in Table V.

TABLE V.—*Number of days between deposition of egg and emergence of beetle of roundheaded apple-tree borer at French Creek, W. Va.*

Date egg was deposited.	Date beetles issued from wood.	Number of beetles.		Number of days from egg to beetle.
		Male.	Female.	
June 18, 1913	June 1, 1915	1	0	713
Do	June 14, 1915	0	1	726
Do	June 8, 1915	0	1	720
June 15, 1914	May 24, 1916	2	0	708
June 18, 1914	do	2	0	705
June 8, 1914	May 25, 1916	1	0	716
June 12, 1914	do	1	0	712
June 18, 1914	May 26, 1916	1	0	707
June 18, 1913	May 27, 1916	1	0	1,073
June 18, 1914	do	0	1	708
June 15, 1914	May 28, 1916	0	2	711
June 18, 1914	do	0	1	709
June 11, 1914	do	0	1	716
June 18, 1913	do	0	1	1,074
June 11, 1914	do	1	0	716
June 16, 1914	May 29, 1916	0	2	712
Total		10	10	

As is shown in Table V, 1 male spent 1,073 days in undergoing development within the tree and 1 female 1,074 days, a 3-year period for each. All the others reached maturity in 2 years, the 9 males requiring on an average 710 days from egg to adult and the 9 females undergoing the same transformation in an average of 714 days.

Records obtained at Winthrop, Me., show that of 24 individuals, none matured in 2 years, 6 issued as beetles in 3 years from the egg, and 18 required 4 years to develop from eggs to adults. No definite records were obtained for individuals requiring longer than 4 years for development and yet observations were made which indicate a 5-year period in some cases. Observations made at Biltmore, N. C., indicate a 2-year period with most individuals in that locality.

THE PUPA.

The pupa (Pl. VII, A), when first formed, is soft and delicate, the color being similar to that of the larva. Within a few days it turns slightly yellowish, the eyes soon take on a dark color, and later the whole body becomes mottled with brown and blackish markings. The pupa occupies a vertical position in the cell and measures from 18 to 25 mm. in length, the females being much longer and more robust than the males.

PERIOD OF PUPATION.

At French Creek, W. Va., practically all the individuals pass through the pupal stage during the period from April 15 to May 15, although the time of pupation and the duration of the stage depend very much on weather conditions. The earliest pupa was found in the field April 12, 1913, and the latest May 20, 1915, although undoubtedly a few may sometimes occur before and after these dates. In the locality mentioned, the entire pupal period for any one year has not been found to extend over 30 days, the pupal stage for a single individual averaging about 20 days. All transforming individuals were found in the pupa stage at Demorest, Ga., on May 1, 1915; at Winthrop, Me., on June 17, 1916; and at Munising, Mich., on June 20, 1917.

As has been stated, the pupæ are sensitive to temperatures, warm weather accelerating and cold weather retarding the changes. After transforming to the adult stage the beetles usually remain within the pupal chamber from 5 to 10 days, the length of this period, too, depending on weather conditions.

THE ADULT.

The adult (Pl. VI, C; VIII, C) is a handsome, elongate beetle, the males averaging 15 mm. in length and the females 20 mm. The back is cinnamon brown with two broad white stripes extending the full length of the body; the front of the head and underparts are silvery white and the legs and antennæ gray, changing to brownish at the extremities. The antennæ of the males are slightly longer than the body and those of the females slightly shorter than the body.

In escaping from the wood the beetles gnaw round exit holes through the bark at the upper end of the pupal chamber, the holes ranging from 5 to 8 mm. in diameter, the larger ones being those from which females issue (Pl. VII, D).

PERIOD OF ACTIVITY OF BEETLES.

The statements of other investigators regarding the length of time that the beetles of the roundheaded apple-tree borer are on the wing indicate that in some places this period may be of longer duration than in any of the localities where the present writer has made observations. Becker (14), in the summary of his paper, says that in the Ozarks pupation begins in the latter part of March and may continue until the middle of June, and on another page speaks of larvæ that pupated as late as July 11, the inference being that this was under normal conditions. The beetles are said by the same author to be on the wing in the Ozarks from the third week of April

until perhaps as late as the last of August. These statements indicate that in the Ozarks beetles continue to issue from the wood over a period of approximately 100 days. Chittenden (7) states that oviposition has been observed from June to September in a single locality (Lawrence, Kans.) and says that at Albany, N. Y., beetles have been observed in the trees as early as April. Felt and Joutel (6) cite statements of observers giving the months of May, June, July, and August as the time when beetles are abroad.

All the rearings of the present writer indicate that the beetles issue from the wood over a much shorter period than has been found by the writers referred to above. The longest periods covered by the emergence of the beetles were at French Creek, W. Va., where, in 1916, 244 beetles issued from May 20 to June 18, a period of 30 days, and in 1917, when 118 beetles issued from May 25 to June 23, a period of 30 days. No beetles in either year issued before the first dates or after the last dates named. In all the rearings of which the dates of issue were kept, including 772 beetles, the first to issue was at Demorest, Ga., on May 8, and the last at Munising, Mich., on July 23, the interval between these two extreme dates being 78 days.

Table VI presents the data which have been accumulated relative to the time of emergence of beetles in several localities.

TABLE VI.—*Periods during which beetles of the roundheaded apple-tree borer issued from the wood in different localities.*

Year.	Locality.	Number of beetles.	First and last emergence.	Number of days.	Periods over which beetles issued from wood.
					May. 5 10 15 20 25 30 | June. 4 9 14 19 24 29 | July. 4 9 14 19 24 29
1911..	French Creek, W. Va.	11	May 23-June 1...	10	
1912..	.....do.....	27	May 14-June 6...	24	
1913..	.....do.....	95	May 12-June 6...	26	
1914..	.....do.....	116	May 22-June 8..	18	
1915..	.....do.....	5	May 25-June 14..	21	
1916..	.....do.....	244	May 20-June 18..	30	
1917..	.....do.....	118	May 25-June 23..	30	
1918..	.....do.....	21	May 18-May 28..	11	
1914..	Weston, W. Va.....	35	May 20-June 2...	14	
1914..	Great Cacapon, W. Va.	13	May 20-June 6...	18	
1914..	Elkins, W. Va.....	16	May 28-June 5...	9	
1914..	Pickens, W. Va.....	24	May 28-June 9...	13	
1914..	Pemberton, N. J.....	1	June 21.....	1	
1914..	Winthrop, Me.....	28	June 18-June 30.	13	
1915..	Demorest, Ga.....	6	May 8-May 14...	7	
1915..	Biltmore, N. C.....	2	May 15-May 20..	6	
1916..	Winthrop, Me.....	8	June 20-July 3...	14	
1917..	Munising, Mich.....	2	July 23-July 25..	3	
	Total number beetles..	772			

LENGTH OF LIFE OF INDIVIDUAL BEETLES.

Eight female beetles whose emergence and death were noted in 1911 and 1912 lived, respectively, 27, 31, 37, 41, 41, 44, 46, and 46

days. In 1912 the first beetles issued from the wood on May 14 and eggs were still being deposited on July 1, 48 days after the first beetles appeared. In 1913 beetles were observed on the wing from May 12 to July 19, a period of 68 days. In 1914 a female issued on May 27 and died July 24, living 58 days. In the same year a male and female were alive on August 6, 76 days after the first beetle issued. In 1917 the first beetle left the wood on May 25 and the last beetle of the year died August 10, beetles thus being on the wing for 77 days. In 1918 two females were observed to be alive and active 61 days after leaving the wood. The beetles referred to above were in all cases kept in roomy wire-screen cages over small, growing apple trees, and it is presumed that their life periods extended over the normal term.

FEEDING HABITS OF BEETLES.

The beetles feed to a considerable extent upon both tender and tough bark of twigs and branches and upon leaf stems and leaf ribs, and they frequently chew ragged holes through the tissues of the leaf. (Pl. IX, A, C.) They were observed often working with their mandibles at the castings ejected from trees by larvæ of their own kind and were seen occupied in a similar manner with damp soil; this was probably for the purpose of obtaining water. One female beetle kept alone in a cage over a young apple tree lived for 58 days, and after her death a careful measurement was made of the leaf and bark surface over which she had eaten. The total area eaten was found to be 6.9 square inches. In another instance two male and three female beetles, which had just issued from the pupal quarters, were placed in a roomy cage over a young apple tree that had been sprayed just before with lead arsenate at a strength of 3 pounds of the paste to 50 gallons of water. Two of the beetles died the first day, one died on the second day, one on the third, and the other, a female, died on the ninth day. All apparently succumbed to the poison, as there was no mortality among beetles caged at the same time over unsprayed trees. Death occurred to all the beetles confined over the sprayed tree before any eggs were deposited. It was noted frequently that beetles differed individually in the amount of feeding done immediately following their emergence from the wood, some proceeding to feed at once and others waiting several days. It is probable that the female referred to above, which lived nine days over the sprayed apple tree, did no feeding until a short time before her death.

COPULATION.

Copulation may take place soon after the beetles issue from the pupal chambers or it may be deferred a week or 10 days, the time

of pairing seemingly depending about as much upon the volition of one sex as the other. Newly emerged males occupying cages in company with females have been observed to wait several days before paying any attention to the females. In other cases they have begun courtship on the day following that of their emergence. The females usually repel the males for several days, but will sometimes receive them within an hour after quitting the pupal quarters. Evidently some individuals of both sexes remain in the wood until they are sexually mature, while others issue before the sex instinct has developed.

The act of copulation usually lasts several hours and is repeated at frequent intervals so long as both sexes live and are active. Pairing was several times noted after the participants had been on the wing from 30 to 40 days.

Females confined by themselves were observed to engage in a performance evidently to attract males. They would occupy the upper surface of an exposed leaf and thrust out the ovipositor to its utmost length and then wave it about while it was being gradually drawn in. A few minutes later the ovipositor would be again extended and then drawn in and so the act would continue for an hour or more. Apparently a scent or influence of some kind was being discharged as a sex attraction, but when females so engaged occupied outdoor cages no wild males of the locality were observed to come to the cages.

DAY AND NIGHT ACTIVITIES OF THE BEETLES.

Early writers on this insect described the beetles as being active nocturnally and secreting themselves by day. The beetles were supposed to issue from their pupal cells and deposit their eggs exclusively by night. The reverse of this habit, however, has been found more nearly true. All the beetles issue from their exit holes by day, usually during the forenoon, although a few continue to come forth during the afternoon hours. No evidence was obtained that oviposition ever takes place in the darkness, although male beetles are occasionally on the wing at night. There is a period of activity in the evening just before twilight when both sexes are especially inclined to flight, but as darkness comes on most of the beetles settle among the branches and remain quiet until the light of the morning.

Observations made at night with electric flashlights indicated that the normal habit is to rest in one place through the night, but that occasionally the beetles move about in the darkness.

DO THE BORERS DIFFERENTIATE BETWEEN VARIETIES OF APPLE?

Orchardists often observe what appears to be a preference on the part of the roundheaded apple-tree borer for certain varieties of

apple. Individual trees or blocks of one kind of apple will be attacked year after year much more extensively than those of other varieties. Becker (14) concludes from experiments that the borer does not discriminate between varieties and that the preference which is often indicated is merely a matter of propinquity.

During the present investigations observations were made bearing on this point over a period of five years in the experiment orchard at Elkins, W. Va., As has been stated, this orchard contained only three varieties, namely: 310 King, 341 Grimes, and 341 York Imperial, the block of Grimes occupying a space through the center of the orchard. All the rows of the three varieties abutted impartially at one end against an older and heavily infested orchard. There were no conditions within or surrounding the orchard that would appear more favorable for the attack of one variety than another, except that female beetles in entering the orchard to oviposit might be expected to alight more frequently on the outer trees. During four of the five years over which counts were made, however, the Grimes in the center were much more severely attacked, practically 50 per cent of the 1,639 borers removed from the trees being found in this block. The King trees, although fewer in number, were second in point of attack, and the York Imperial trees suffered least. This ratio of attack, as may be seen from Table VII, was constant for the years 1913, 1914, 1916, and 1917. In 1915, which was the year of lightest infestation, the York Imperials were first in point of attack, the Grimes second, and the Kings third.

TABLE VII.—*Relative extent of infestation by the roundheaded apple-tree borer of three varieties of apple for a period of five years.*

Year.	Variety of apple.					
	King.		Grimes.		York Imperial.	
	Number of borers.	Per cent.	Number of borers.	Per cent.	Number of borers.	Per cent.
1913	49	30.3	77	47.5	36	22.2
1914	80	33.5	110	46.0	49	20.5
1915	8	8.3	43	44.8	45	46.9
1916	223	35.4	283	44.8	125	19.8
1917	121	23.7	303	59.3	87	17.0
Total	481	29.3	816	49.8	342	20.9

It is entirely possible that the results which are shown in Table VII are accidental, and yet it must be confessed that, aside from varietal preference on the part of female beetles while ovipositing, there is no apparent way of accounting for the almost constant maximum attack of Grimes and minimum attack of York Imperial.

DISTANCE OF FLIGHT OF FEMALE BEETLES DURING OVIPOSITION.

The probability that the female beetle during her egg-laying activities does not normally wander far in search of host trees has been suggested by the fact that the trees containing the larvæ are usually found in somewhat restricted groups. This grouping of the borers occurs not only in orchards but in the woods as well, and indicates that where host trees grow near together the adult females during oviposition are not inclined to fly far from the trees in which they develop. In an effort to obtain data bearing on this point several experiments were carried out in West Virginia, which are described below.

THE DARNALL ORCHARD.

This orchard contained 537 apple trees ranging in age from 4 to about 20 years. In the summer of 1914 it was found to be badly infested with roundheaded apple-tree borers, and the trees were gone over carefully after the eggs of the current season had hatched, all the borers being removed and counted. The trees contained 141 borers, 106 of which had only recently hatched. The orchard was surrounded by pasture lands and woods in which grew an abundance of seedling apple, wild crab apple, hawthorn, and service trees. Within a strip 600 feet in width surrounding the orchard these outlying trees were also examined and all the borers removed and counted, the number of borers found being 95. This operation was repeated annually for a period of 4 years, it being obvious that if borers were not allowed to breed within the area all the young borers found within the orchard after the first year would necessarily have hatched from eggs deposited by female beetles which had flown into the orchard from outside the 600-foot strip.

In the second year of the experiment (1915) an examination of the orchard trees showed that female beetles had crossed the 600-foot strip and deposited 56 eggs. The third year (1916) only 1 egg was deposited in the orchard. The fourth year (1917) beetles flew across the boundary strip and deposited 44 eggs in the orchard trees. While this was a considerable reduction from the number of eggs deposited annually in the orchard before the experiment began, still it showed a rather general tendency on the part of the female beetles to fly at least 600 feet in searching for trees in which to oviposit.

In figure 2 are given plats of the Darnall orchard showing the location of infested trees and the number of borers found at each of the four annual examinations.

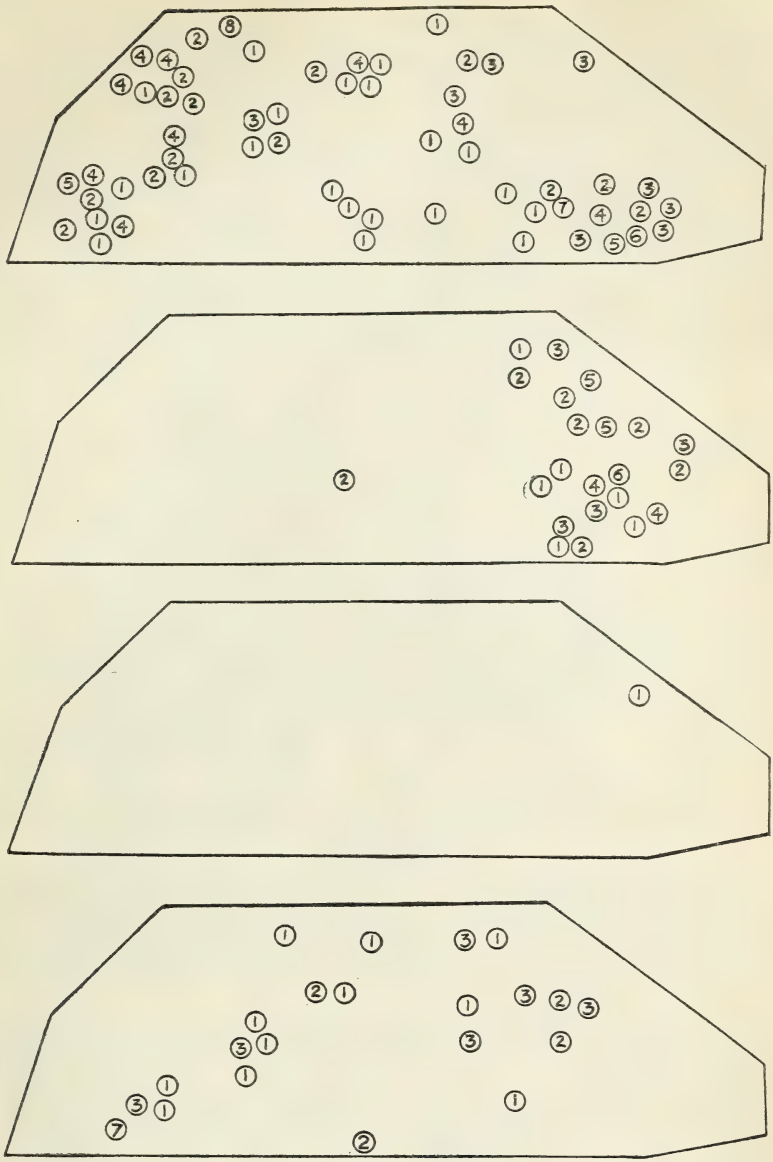


FIG. 2.—*Saperda candida*. Plats of Darnall orchard illustrating distance of flight of female beetles during oviposition. Circles represent location of infested trees and the figures within them show number of borers found. No beetles were allowed to develop within 600 feet of the orchard. Plat 1: Position of infested trees and number of borers found at first examination (1914). Trees contained 106 young borers and 35 from eggs of previous seasons. Plat 2: Position of 56 borers developing from eggs deposited in 1915 by beetles that had flown into the orchard from outside the 600-foot strip. Plat 3: Position of one egg deposited by female which entered the orchard from outside the 600-foot strip in 1916. Plat 4: Position of 44 eggs deposited by beetles which entered the orchard from outside the 600-foot strip in 1917.

THE PAGE ORCHARD.

The Page orchard, like the Darnall orchard, was found in 1914 to be heavily infested with roundheaded apple-tree borers. The trees within the orchard and within a strip 300 feet in width surrounding the orchard were cleaned of borers. The orchard contained 464 trees from which were removed 290 borers, 254 of which were from eggs of the current season. This orchard was surrounded entirely by pasture lands over which grew scattering seedling apple, crab apple, and hawthorn trees in which many borers were developing. The second annual examination, which was made in August, 1915, showed that 55 eggs had been laid in the orchard trees. One

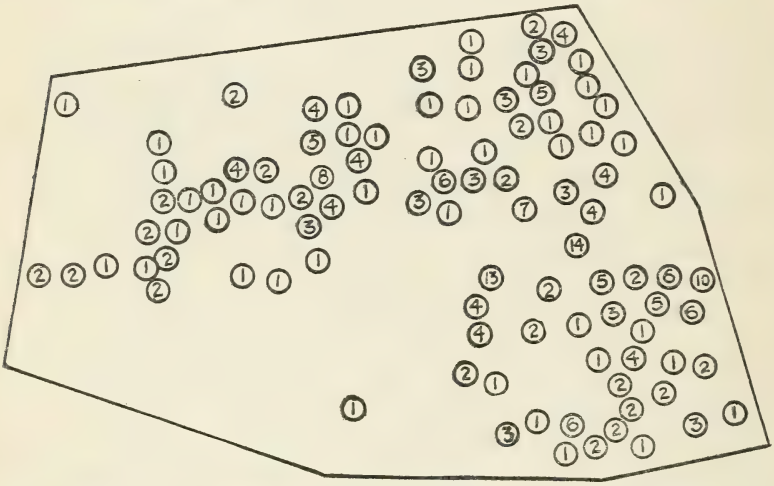


FIG. 3, *A*.—*Saperda candida*. Plat of Page orchard illustrating distance of flight of female beetles during oviposition. Circles represent locations of infested trees and the figures within show number of borers found. Orchard surrounded by 300-foot strip cleaned of borers. Plat 1: Infested trees and number of borers found at first examination (1914). Orchard contained 290 borers, 254 of which developed from eggs of the current year.

borer had been overlooked in the orchard during the examination of the previous year and this had developed into an adult female, as was apparent from the size of the exit hole, and near to the tree from which it issued two trees were found containing, respectively, 4 and 9 young borers. In another part of the orchard a group of 7 trees contained 42 young borers. This group of infested trees was near the outer border of the orchard, and 275 feet distant another fresh female exit hole was found in a seedling apple growing in the pasture field, the author of which had been overlooked the previous year. It seemed probable that this beetle had flown to the orchard and that the two females overlooked the previous year were responsible for all the eggs which were deposited within the orchard in 1915.

The third year (1916) 38 eggs were distributed among 10 of the orchard trees, all evidently having been laid by females that flew into the orchard over the 300-foot strip.

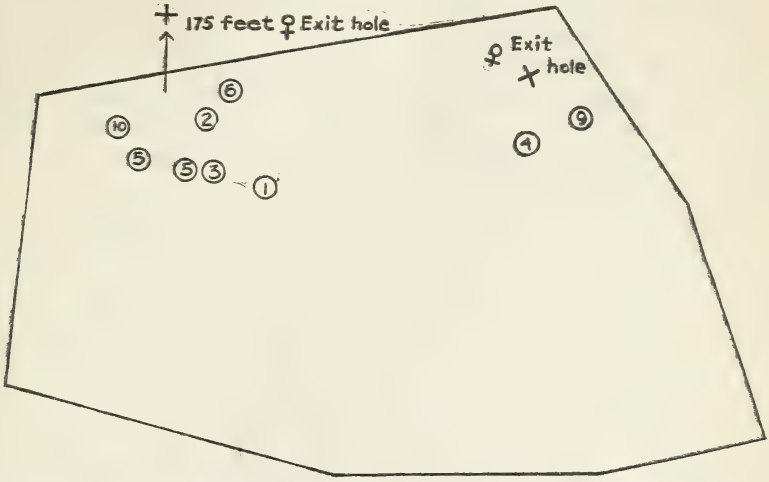


FIG. 3, *B.—Saperda candida.* Plat of Page orchard illustrating distance of flight of female beetles during oviposition. Circles represent locations of infested trees and the figures within show number of borers found. Orchard surrounded by 300-foot strip cleaned of borers. Plat 2: Number of borers found in second examination (1915). Fifty-five borers present from eggs of current season. Crosses indicate where two female beetles issued that had been overlooked as borers during the previous annual examination.

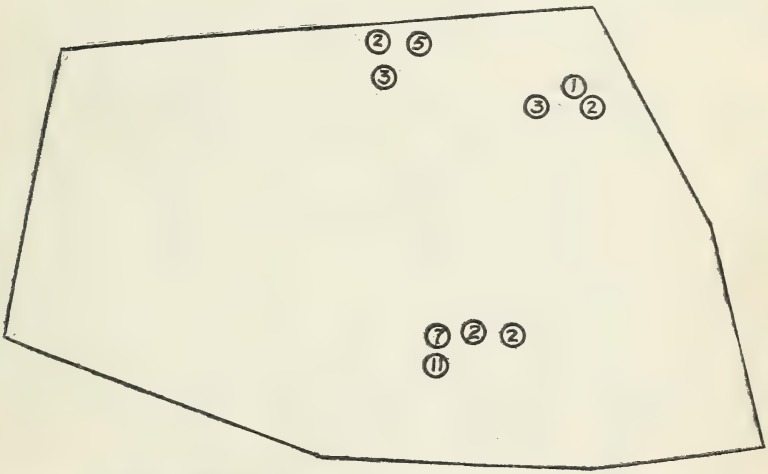


FIG. 3, *C.—Saperda candida.* Plat of Page orchard illustrating distance of flight of female beetles during oviposition. Circles represent locations of infested trees and the figures within show number of borers found. Orchard surrounded by 300-foot strip cleaned of borers. Plat 3: Number of borers found at third examination (1916). Thirty-eight borers were present, all having evidently hatched from eggs deposited by females which had entered the orchard across the 300-foot strip.

The Page orchard and the strip surrounding it were kept clean of borers for three consecutive years. The plats above (fig. 3) show the condition of the orchard as to infestation at each examination.

It will be seen that the results of the experiment in the Page orchard were fully as good as those obtained in the Darnall orchard, although the cleaned strip surrounding the trees was only half as wide. This may be accounted for by the fact that the breeding conditions for borers surrounding the Page orchard were much less favorable than those surrounding the Darnall orchard and fewer beetles were developing in the locality.

The results of the experiments described and illustrated above for determining the distance which beetles will fly during the period of oviposition are suggestive although not entirely conclusive. It will be noted that every year in both orchards after the experiments began there is evidence that female beetles crossed the surrounding strip of borer-cleaned territory to oviposit in the orchard. In all cases, however, there was a decided improvement in the borer conditions within the orchards after the development of beetles within cases, however, there was a decided improvement in the boror conditions of infestation on the number of young borers found in the orchards at the first examinations, we have thereafter percentages of borer reduction which may be tabulated as follows:

TABLE VIII.—*Improvement in roundheaded apple-tree borer conditions derived from preventing the development of adults within and adjacent to the orchards.*

Name of orchard.	Year.	Width of cleaned-up strip surrounding.	Number of borers found.	Percentage of gain.
		Feet.		
Darnall	1914	600	106	
Do	1915	600	56	47.1
Do	1916	600	1	99.1
Do	1917	600	44	58.5
Page	1914	300	254	
Do	1915	300	55	78.3
Do	1916	300	38	85.0
Total average gain in both orchards				73.6

As is shown in Table VIII, the average improvement in borer conditions in both orchards derived from the stopping of the development of adults in the immediate localities was 73.6 per cent.

FURTHER TEST OF THE FLIGHT OF FEMALE BEETLES.

One of the orchards used in experiments dealing with the roundheaded apple-tree borer contained 992 young apple trees planted in 31 rows of 32 trees each. Row 1 extended parallel with the outer row of an older orchard that was heavily infested with borers, the experiment orchard being surrounded on other sides by grown-up

fields in which scattering seedling apple and service trees grew. Undoubtedly beetles developed within these outstanding trees and flew into the experiment orchard to oviposit, providing thereby for an unknown number of borers, which can not be eliminated from the numerical results of the experiment described below. The rather heavy infestation, shown below, of rows 1 to 5 can be accounted for only on the ground of an overflow of adult females from the adjacent older orchard.

In the experiment orchard during three separate years newly emerged beetles of both sexes were distributed among the trees of row 16, which extended through the center of the orchard. The beetles used were removed from rearing cages and placed on the trunks of the trees, care being exercised to disturb or excite them as little as possible. The sexes of the beetles were about equally divided as to numbers. After a sufficient time had elapsed for all the eggs to hatch which were deposited by the liberated females, the orchard was gone over and the number of borers found in each row recorded. The results showed with some degree of accuracy the extent to which the females in ovipositing wandered away from the trees upon which they were liberated. In 1914, 25 females were liberated on row 16; in 1916, 87 females were liberated on the same row; and in 1917, 12 were distributed in like manner. In the year 1915, nine females were liberated on row 29. In all cases males accompanied the females.

Table IX shows the distribution by rows of the borers found in the orchard each season following the liberation of the female beetles on row 16.

TABLE IX.—*Distribution of roundheaded apple-tree borers hatching principally from eggs deposited by female beetles liberated on the central row of the orchard. Orchard contained 31 rows of 32 trees each and beetles were placed on row 16.*

No. of row.	Number borers found.			Total.	No. of row.	Number borers found.			Total.
	1914	1916	1917			1914	1916	1917	
1	1	20	25	46	17	18	23	28	69
2	3	23	13	39	18	7	25	19	51
3	5	23	23	51	19	9	14	21	44
4	2	23	23	47	20	5	29	21	55
5	1	22	2	25	21	7	19	24	50
6	2	14	9	25	22	12	13	22	47
7	9	21	4	34	23	10	12	12	34
8	3	28	7	38	24	9	14	23	46
9	22	24	7	53	25	9	11	18	38
10	9	21	7	37	26	8	14	3	25
11	3	12	8	23	27	3	26	8	37
12	14	19	19	52	28	7	21	6	34
13	12	31	9	52	29	1	18	18	37
14	10	10	18	38	30	6	12	14	32
15	7	30	26	63	31	1	31	18	50
16	24	29	50	103					

Total number borers 1,375

Table IX shows that in row 16, where the adult females were liberated, the total number of borers for the three years was greater than in any other row of the orchard. It shows also that a few rows on each side of row 16 contained considerably more than the average number of borers for the other rows of the orchard.

In 1915 nine female and several male beetles were liberated on row 29. A later examination showed that this had resulted in the greatest number of borers occurring in row 29, the central rows of the orchard having this year the fewest borers.

The results shown in Table IX and the distribution of the borers found in 1915, when the females were placed on row 29, are set forth graphically in figure 4.

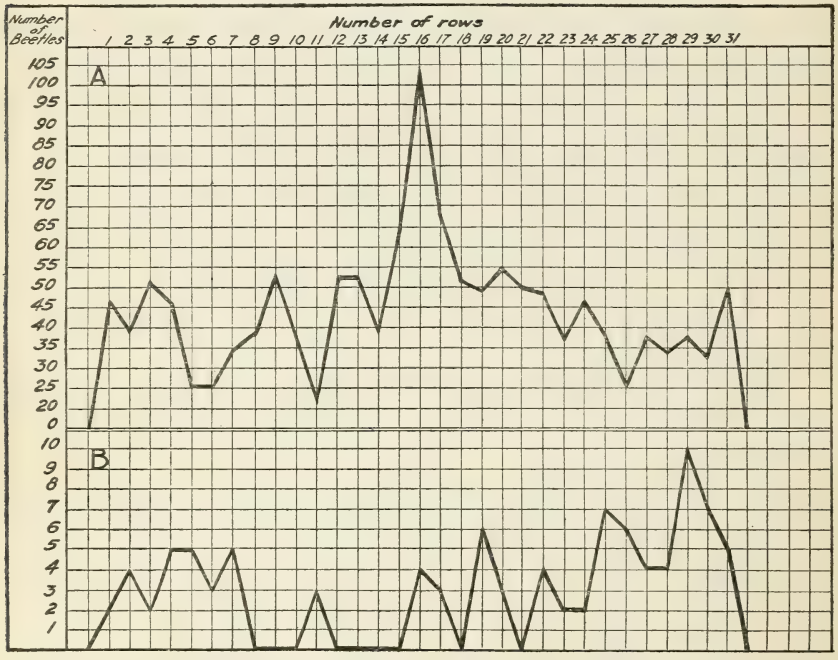


FIG. 4.—*Saperda candida.* Diagram showing tendency of female beetle to refrain from long flights during oviposition. *A,* Number and distribution of borers found in orchard after liberating 124 female beetles during three separate years on row 16. *B,* Number and distribution of borers found after liberating 9 females on row 29.

All the foregoing data on the flight of the female point to a constant tendency on her part to deposit eggs near the place of her development. They also afford good evidence that the female beetle is capable of flights of considerable distance when impelled by any special desire.

In one case when a female was liberated in the manner described above, she immediately took wing and arose to a height of 30 or 40 feet and then disappeared in the direction of a tract of woods about

500 yards distant. That such flights are unusual, however, is indicated by all the evidence that could be gotten.

FEMALES LESS PRECOCIOUS THAN MALES.

The females are not only less active in flight and more sluggish generally than the males but are regularly two or three days behind the males in issuing from their pupal quarters in the wood. This constant tendency on the part of females to be slower than the males in emergence is illustrated by figure 5.

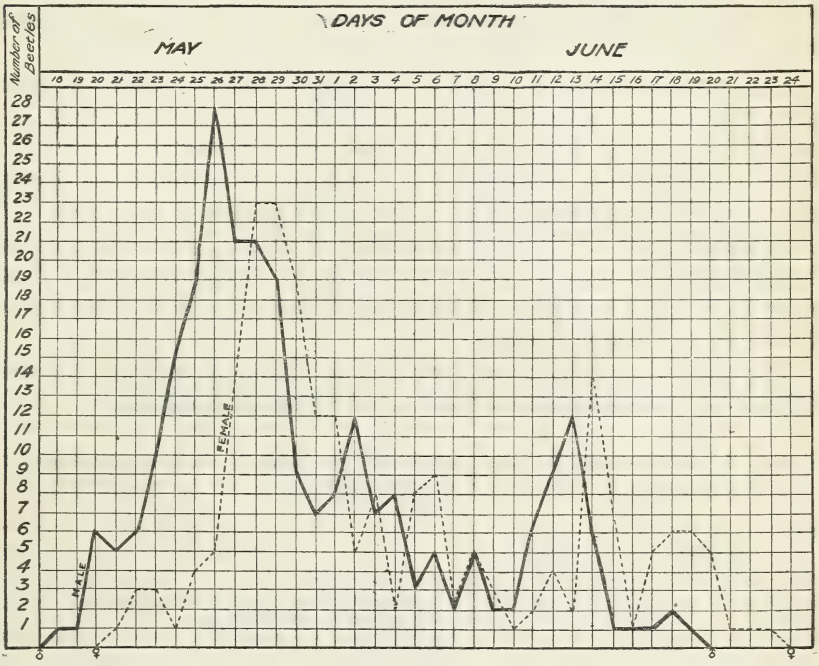


FIG. 5.—*Saperda candida*. Diagram illustrating the relative time of emergence of male and female beetles. Based on 261 males and 206 females that issued under natural conditions at French Creek, W. Va., in 1914, 1915, 1917, and 1918.

SEASONAL PHENOMENA OF THE HOST TREES AS AN INDEX TO THE TIME OF DEVELOPMENTAL CHANGES OF THE INSECT.

Since this borer occurs in North America from southern South Carolina and Texas northward into Canada the calendar dates of its metamorphic changes in different latitudes must vary considerably. There must also be a considerable yearly variation in the dates of these changes in any given locality, due to the early or late advent of spring.

In the rearing work with this species it was found that between Demorest, Ga., and Winthrop, Me., there was a difference in time of

emergence of the first beetles of about 40 days. On Grand Island, in northern Michigan, the first beetles appeared 75 days after the date of the first appearance in Georgia. In the several years during which beetles were reared at French Creek, W. Va., there was a variation of 13 days in the dates of the first adults to issue. Calendar dates are therefore of little value in expressing the time when a given metamorphic change of the insect takes place. It was found, however, that the time of certain transformations and activities of the borer may be anticipated or determined very conveniently by observing the definite annual steps in the development of foliage, flowers, and fruit of the apple and other trees upon which the insect lives.

The first blossoms to appear on apple follow closely the first activities of the borers in the spring and it is just in advance of apple blossoming time that the first fresh castings thrown from trees by borers may be looked for. Also, the blooming time of apple corresponds quite definitely with the pupal period of the insect. The oviposition time of the beetles begins with and extends somewhat beyond the ripening season of the fruit of the service tree. These rules hold good in a general way for all latitudes and altitudes and for early and late springs.

The following field notes arranged in Table X indicate the coincidence of these events in a number of different localities:

TABLE X.—*Indicating the correspondence in time of certain developmental changes in the roundheaded apple-tree borer and its host trees.*

Locality.	Date.	Field note.
Frenchton, W. Va.	Apr. 27, 1914	Blossoms of York Imperial and Maiden Blush one-half open. One pupa of *S. candida* found.
Weston, W. Va.	Apr. 28, 1914	Apple trees in full bloom. More than half the transforming borers have pupated.
Great Cacapon, W. Va.	May 5, 1914	Apples a little past full bloom. About 25 fresh pupæ of *S. candida* collected.
Pickens, W. Va.	May 20, 1914	Three-fourths the apple petals off. Maturing borers all in pupal stage.
Winthrop, Me.	June 22, 1914	Apple blossoms have been off 2 weeks or more. Pupæ of *S. candida* still present. A few have issued.
Gadsden, Ala.	Apr. 29, 1915	Apple petals have been off 6 days. One pupa of *S. candida* found.
Demorest, Ga.	May 1, 1915	Apple trees just past full bloom. All maturing *S. candida* in pupal stage.
Biltmore, N. C.	May 4, 1915	Do.
French Creek, W. Va.	Apr. 20, 1916	First apple blossoms opened to-day. Half the transforming borers have pupated.
Do.	Apr. 25, 1917	First apple blossoms opened Apr. 22. All maturing borers have pupated Apr. 25.
Do.	Apr. 27, 1917	Borers in apple threw out first castings a few days in advance of first apple blossoms.
Munising, Mich.	June 20, 1917	First apple blossoms opening. About a dozen fresh pupæ of *S. candida* found.
French Creek, W. Va.	Mar. 26, 1918	Apple buds showing first pink. Fresh castings first appearing from 1-year-old borers.
Do.	May 15, 1918	Last petals falling from apple. Transforming borers all pupæ except one male which has changed to beetle.
Do.	June 13, 1914	First fruit of service ripened May 29. First eggs of *S. candida* June 4. Fruit of service overripe June 13. Egg laying of *S. candida* at height June 13.

NATURAL ENEMIES.

Possibly no other economic insect of equal importance has had so few natural enemies recorded definitely and specifically as has the roundheaded apple-tree borer. In all the literature upon this borer, there seems to be only one original reference to such an enemy, this being the single instance of the hymenopterous parasite *Cenocoelius populator* Say, reared about 30 years ago by Riley and Howard (3, p. 59) from borers of this species received from Indiana. Felt and Joutel (6) state that an undetermined carabid larva was found preying on the borers by Walsh and Riley, and practically all observers have noted that woodpeckers are an important enemy, although in no case is the specific identity of the bird or birds established, so far as the records show.

In rearing and handling many thousands of the borers in various localities the writer has never found any evidence of hymenopterous parasites. In two instances undetermined carabid larvæ were found devouring young borers in West Virginia and another half-grown borer was found that had been killed by a hairworm, sections of the worm being found in the burrow entwined around and within the dead and shriveled body of its host. A large spider was seen to pounce upon and bite in the back a female beetle that had just issued from her exit hole in a tree. In an effort to rescue the beetle the spider was crushed beyond recognition. The beetle died a few hours later from the wound.

WOODPECKERS.

While the control effect of parasites and predacious insects on this borer is negligible, woodpeckers play an important part in holding it in check. Wherever the writer has collected specimens or made observations in borer-infested localities the work of these birds has always been in evidence. Soon after the borers hatch the woodpeckers begin to find them beneath the thin covering of bark and thereafter the birds drill for them as long as they are in the tree. In several orchards where counts were made from 50 to 75 per cent of the borers had been destroyed in this way.

During October, 1915, 24 young borers were collected and planted in furrows gouged out of the wood beneath loosened tongues of bark on the trunk of an apple tree. A week later, when the tree was revisited for the purpose of putting a wire screen around the trunk to protect the borers from birds, woodpeckers had punctured every tongue of bark and removed the borers from beneath. Not one had escaped. In May of the same year, while pupæ were being collected from an orchard, a total of 11 pupal cells were found and from every one the occupant had been removed by woodpeckers. In another case

21 pupal cells were found, 19 of which had been opened by woodpeckers and the insects removed.

During the winter of 1915 the writer had standing near his office window a young apple tree in which there were known to be three borers ready to pupate the following spring. The borers had been protected previously by a wire screen but now the screen was removed. On December 21 a male downy woodpecker, *Dryobates pubescens medianus* (Swains), was observed to alight on the base of the trunk and move about alternately tapping the bark and assuming a listening attitude. Presently, with a few vigorous strokes, it drilled through the bark at the point where the future exit hole of a beetle was to have been and at once drew forth and swallowed a large borer. (Pl. V, B.) A minute or two later it located a second borer, disposed of it in the same way, and then flew away without further search. Again, in January, 1916, the trunk of a young apple tree known to contain full grown borers was planted in a natural position near the same office window. A few days later a pair of downy woodpeckers came to the tree and after a brief search the female was seen to remove and swallow a borer. A little later the male found and removed another. The birds would move about over the trunk tapping lightly with their beaks until the quarters of a borer were located. Then with a few sharp strokes they would penetrate to the burrow and remove and devour the insect. The female bird located and removed her specimen through the partly prepared exit hole in less than a minute, but the male drilled industriously for his nearly five minutes, making during the time several openings into the wood which extended in a line over the burrow made by the borer in ascending the trunk to prepare its pupal chamber.

Other observations were made which indicate that the hairy woodpecker, *Dryobates villosus villosus* (L.), also destroys the borers, but this bird was not seen in the act of removing the insects from the tree.

METHODS OF CONTROL.

Ever since the roundheaded apple-tree borer was first recognized as a serious orchard pest, two principal ways of combating it have been advocated: First, the worming process, in which the borers are removed from their feeding places in the tree by the use of a knife and other tools (Pl. IX, B); and, second, the covering of that portion of the trunk of the tree where the eggs are most frequently laid with some protective wash, paint, or mechanical device which will act as a barrier against the female beetles during oviposition. Both of these methods are commonly practiced in orchards and have been the lines of most frequent and extensive experimentation by investigators of borer injury and control. In the present studies, modifications of

these two methods have received special consideration. Tests were made of the effects of penetrating liquids of an irritating or poisonous nature when applied to the bark beneath which borers were feeding, of gaseous and poisonous liquids injected into the burrows, of sticky substances applied to the trunks of trees for the purpose of entangling the adults during their egg-laying activities, and of killing the adults by the use of poisonous sprays. Studies were made also of the distance which female beetles may fly in search of trees in which to oviposit, with the idea of determining the possibility of preventing the infestation of orchards by destroying near-by breeding places. These various tests are described in detail below under their various headings.

WORMING.

The labor of removing borers from trees with a knife and wire is not relished by the majority of orchardists, and yet the difficulties and expense of the task are less than in many other necessary operations in dealing with insect and fungous enemies. Two men, on an average, with an insignificant expenditure for tools and material, should worm 500 trees in a day and obtain as high a percentage of control as ordinarily results from a spraying operation against the codling moth or San Jose scale. Not only does a thorough worming of an orchard rid the trees of the borers present at the particular time but it insures a decreased number of borers for the following one or two years. As is shown on pages 20 to 24, by preventing adult borers from developing within and adjacent to an orchard a reduction may result of about 75 per cent in the number of borers that will attack the orchard the ensuing year.

The process of worming is well understood; the best tools for the purpose being a garden trowel for removing the earth and litter about the trees, a pocketknife with a long, sharp blade, a narrow chisel for securing borers that have penetrated deep into the wood, and a piece of slender wire (Pl. IX, B) about a foot in length with a sharp hook bent at one end and a tag or bit of conspicuous cloth attached to the other end to safeguard the wire against loss. These tools may be carried conveniently in a small fruit basket. The writer found that worming can best be done by two men working together on opposite sides of the tree. With a little practice, one becomes quite adept at locating burrows and hooking the borers from their retreats. After a little skill has been acquired the chisel will have to be used only on rare occasions when deep burrows in the wood are found to be so crooked that the wire on being inserted will not follow the openings.

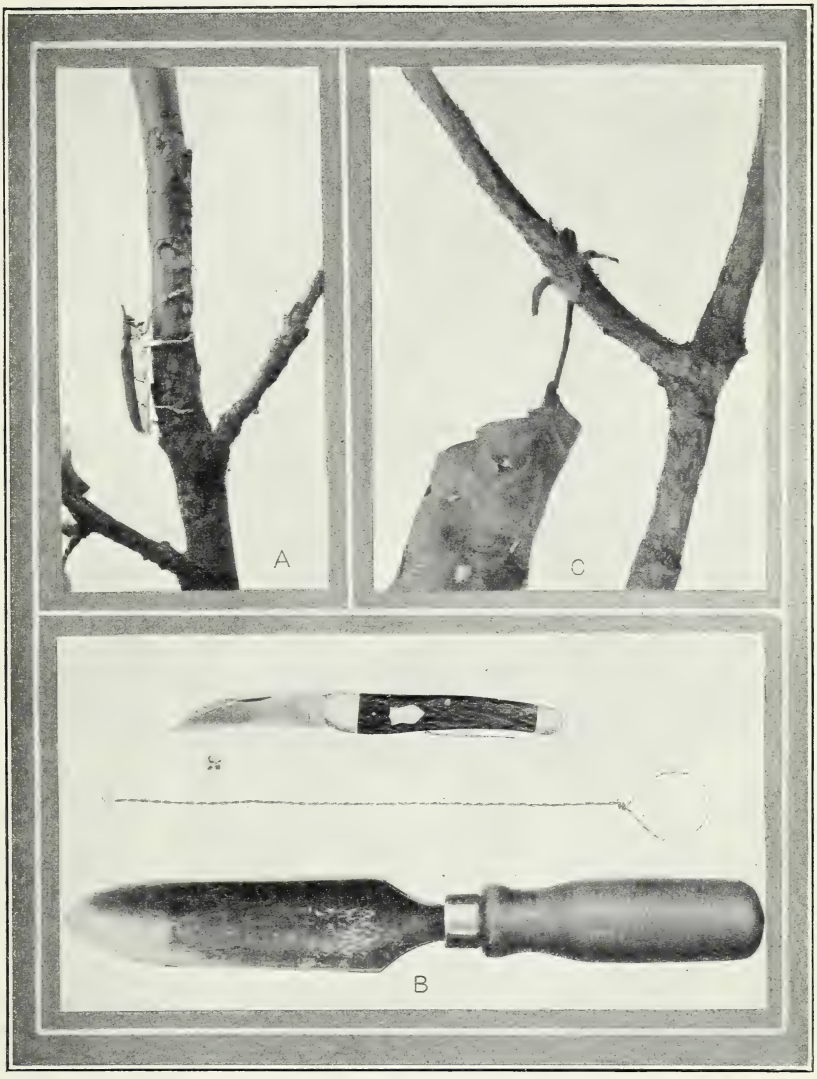
Worming should be done as soon as possible after the last eggs of the year have hatched, as young larvæ usually feed rapidly and

often injure small trees severely the first season. The proper time for the autumn worming varies two months or more between the southern and northern limits of the insect's range, and no definite date can be given which applies to all localities. A safe rule is to have the worming job over before the time arrives for gathering the first winter apples. The borers continue to injure the trees during warm weather of late autumn and early winter, often ejecting their castings in the latitude of West Virginia as late as December 1. It is best to prevent all possible injury by getting the worming done previous to the press of apple-picking time. Trees should have a second worming in the spring soon after the blossoming time of the apple, as it is practically impossible to secure all the borers at one examination. Borers are usually easy to locate by their fresh castings soon after apple trees bloom. (Pl. VII, B.)

At present no cheaper or more effective method of combating this borer is known than that of worming. In order to get best results, however, the work in the orchard must be done thoroughly, and near-by breeding places, such as scattering growths or clumps of apple, wild crab, mountain ash, hawthorn, and service trees eliminated either by destroying the trees or by worming. Many orchards are wormed thoroughly every year, and just as regularly beetles developing in adjacent trees fly over the fence and provide annually for other generations of borers. For most effective control, therefore, the worming operation should include not only the orchard but the trees of the locality immediately surrounding the orchard in which borers breed, and the trees should be examined twice annually, first in late summer after the egg-laying season is past and again in the spring after the blossoming time of the apple.

WASHES, PAINTS, AND MECHANICAL PROTECTORS.

Various materials and devices have in the past been applied to the trunks of trees, either to prevent the female beetles from getting at the bark to oviposit or to kill the borers while feeding in the bark or wood. For preventing oviposition protective coverings, either of a liquid or mechanical nature, have been tested, and, for killing the borers, penetrating poisonous or irritating liquids have been recommended. In the present investigations about 50 kinds of washes, paints, and mechanical devices were tested as to their effectiveness in preventing egg laying and for killing the borers within the trees. Many of these materials were homemade or homemixed and many others were commercial products purchased either from the manufacturers or on the market. Nothing in the way of trunk protectors was tested, however, that gave satisfactory results in all cases. Some applications afforded full or a considerable measure of protection against



ROUNDHEADED APPLE-TREE BORER.

A, Beetle gnawing bark from apple branch. B, Tools for use in worming trees. C, Apple branch denuded of bark by beetles.

ovipositing females but could not be applied safely to trees on account of the injury to bark or wood. All degrees of tree injury were obtained, consisting of a slight yellowing and dropping of the leaves, checking of growth, roughing and cracking of the bark, rank growth of water sprouts, and killing outright. Some forms of protectors caused the beetles to lay their eggs higher up the trunk than is the custom, the only apparent advantage in their use being that the resultant borers were easier to get at in the worming process. Some other materials, such as white-lead paint, gave excellent results in certain cases, and in others where the same material was used in the same way, the female beetles bit through the coat of paint and deposited eggs freely in the bark beneath. In practically all cases, the time and expense required to make and apply protectors of this entire class are greater than those called for in the worming operations, and the results in controlling the borers are less satisfactory.

PROTECTORS USED AGAINST OVIPOSITING BEETLES.

Since a large proportion of the eggs of this borer are normally deposited within the bark of a limited space just above the ground, it would seem a simple matter to cover or protect in some way that part of the trunk so as to force ovipositing females to go elsewhere to lay their eggs. A considerable number of such protectors were tried over a series of years in a young apple orchard of a thousand trees planted for experiment purposes at Elkins, W. Va. The orchard was set in rows of 31 trees each, and most of the materials were applied to trees of a single row, leaving the trees of an adjoining row untreated to be used as checks. In every case where paint-like materials were used for more than one year fresh applications were made annually. This was necessary for the reason that the growth of the trees caused all substances to crack and expose areas of the bark. The results of several of these tests are given below in Table XI.

Table XI shows that a considerable measure of control was obtained by most of the protectors used. None, however, was entirely satisfactory in every respect.

In addition to the protecting materials mentioned in Table XI, a large number of others were tested. These included proprietary and commercial products in the form of paints, soaps, tar products, whitewash combinations, viscous substances, nicotine washes, and paper and metal contrivances, all intended to keep the female beetles away from the bark either by offering mechanical barriers or by making approach to the bark so difficult or disagreeable that they would go elsewhere to oviposit. None of these was without objectionable qualities, either from the high cost, injury to trees, or lack of effectiveness in keeping out the borers.

TABLE XI.—*Effects of various protectors applied to the trunks of apple trees to prevent beetles of the roundheaded apple-tree borer from ovipositing in the bark.*

Kind of protector used.	Number of trees treated.	Number of years used.	Number of borers found each year in treated trees.					Total number of borers in treated trees.	Number of borers found each year in check trees.					Total number of borers in check trees.	Per cent borers were reduced by treatment.	Remarks.
			1913	1914	1915	1916	1917		1913	1914	1915	1916	1917			
White lead and boiled linseed oil	31	5	0	4	2	4	2	12	4	7	25	13	10	59	79.7	No injury to trees.
White lead and raw linseed oil	31	5	5	6	3	12	11	37	12	23	5	29	28	97	61.9	Do.
Commercial white-lead paint	31	4	.....	1	0	9	8	18	.....	12	2	48	40	102	82.4	Do.
Axle grease	25	2	0	0	.....	.....	.....	0	9	4	.....	.....	.....	13	100.0	Trees killed.
Gas tar	31	3	8	1	0	.....	.....	9	9	14	25	.....	.....	48	81.3	Trees severely injured.
Soft potash soap	31	3	.....	9	0	8	.....	17	.....	10	2	17	.....	29	41.4	No injury to trees.
Asphaltum	31	4	2	5	0	11	.....	18	4	7	25	13	.....	49	63.3	
Whitewash	31	1	12	.....	.....	.....	.....	12	.....	13	.....	.....	.....	13	.7	Do
Whitewash and glue	31	2	.....	.....	0	20	.....	20	.....	.....	8	24	.....	32	37.5	Do.
Lime-sulphur wash	31	5	5	4	0	16	9	34	8	12	2	48	40	110	69.0	Do.
Tarred-paper wrappers	11	2	0	0	.....	.....	.....	0	1	1	.....	.....	.....	2	100.0	Trees killed.
Burlap wrappers	31	1	9	.....	.....	.....	.....	9	9	.....	.....	.....	.....	9	0	Little injury. Eggs laid above wrappers.
Wire-screen wrappers	31	1	6	.....	.....	.....	.....	6	16	.....	.....	.....	.....	16	62.5	Little injury to trees.
Grass and brush around trunk	25	1	8	.....	.....	.....	8	8	.....	.....	.....	.....	5	5	37.5—	Grass and weeds kept mowed around check trees.
Ground around trunk smooth	31	1	.....	.....	.....	.....	7	7	.....	.....	.....	.....	6	6	14.3—	

A series of tests were made with applications of casein and glue in varying combinations with gypsum, paris white, china clay, sylex, barytes, zinc white, and other pigments, but none of the materials had sufficient lasting qualities to recommend them.

WHITE-LEAD PAINT.

Nothing in the foregoing line of protectors gave better results from every standpoint than white-lead paint. As is shown in Table XI, three forms of this paint were used, one in which the lead was mixed with boiled linseed oil, one with raw linseed oil, and one ready-mixed paint purchased on the market. The first two mixtures were applied annually to 31 trees each for six years and the last to 31 trees for four years. At the end of the periods none of the trees showed any injury, growth being normal and comparable in every way with that of check trees growing in adjacent rows. The total number of borers found during the entire periods of treatment in the trees painted with white lead was 67, the number found in an equal number of check trees during the same period being 258. This shows for the paint a control efficiency of 74.3 per cent.

In one test of paints a large wire-screen cage was built over a clump of 15 4-year-old apple trees in a neglected nursery row. Three of the average-size trees were painted at the base with white-lead paint, 3 with a proprietary tree paint, and 9 were left untreated. As soon as the paint was dry, 7 male and 7 female beetles that had just issued from apple wood were confined in the cage. At the end of the season an examination showed that 193 eggs had been laid by the 7 females, every egg being in the 9 untreated trees, the paints showing 100 per cent efficiency in control. The same season a female beetle that was ready to oviposit was removed from a cage and placed on the trunk of an apple tree in the orchard that had been treated with white-lead paint in the same way as those in the cage. When liberated the female at once crawled up the trunk to a point above the paint, made a slit in the bark, and deposited an egg. She then moved down near to the ground, and, with no apparent difficulty, bit a hole through the paint, made the oviposition slit in the usual way, and placed an egg in the opening. These and other observations showed that the beetles can very easily oviposit through the paint but prefer to place their eggs in the natural bark.

It was very noticeable that some of the borers hatching from eggs deposited beneath a coat of white-lead paint were at first affected deleteriously by the oil which penetrated into the bark. They were slow in getting a start, fed but little, and, in a few cases observed, died within a few weeks after hatching without having made any perceptible growth. Others that were able to burrow deeper into the tissues, beyond the effect of the oil, grew and developed normally.

Considering the ease with which white-lead paint can be procured, the nominal cost of applying it, its noninjurious effect upon the tree, its frequent deterring effect upon the young borers, and its degree of efficiency in preventing oviposition in the tree, the observations of the writer indicate that where protectors of this general class are desired this paint is preferable to other materials. Such paints or protectors as are described above should be applied to the lower portions of the trunks of trees soon after the blossoming time of the apple.

APPLICATIONS FOR KILLING BORERS IN THE TREE.

Various attempts were made to kill the borers, especially while they were young and near the surface, by applying penetrating poisonous and irritating liquids to the bark. With the same object in view, gaseous liquids were also injected into the burrows of larvæ in all stages of development. The details of several of these treatments follow.

NICOTINE SULPHATE.

In September, 1918, 26 apple trees infested with roundheaded apple-tree borers were located, all the burrows opened with a knife, and about a teaspoonful of 40 per cent nicotine sulphate, at a strength of 1 part to 20 parts of water, injected into the opening with a medicine dropper. In all, 67 burrows were treated. An examination made a month later showed that 26 small borers had been killed and 41 of all sizes were alive and active. It was apparent that where the liquid had come into direct contact with the borer death resulted, but where the liquid did not reach the insect no effect was discernible. In another test 29 burrows were treated in a similar manner with 40 per cent nicotine sulphate undiluted. A later examination showed that 21 borers were killed and 8 were uninjured. Of those killed all except one was of small size and all had apparently been doused with the liquid at the time of the application.

In making the opening into the burrow through which to inject the liquid, care had always to be exercised to avoid killing the smaller borers with the knife. The results of the tests showed that this treatment is impracticable. Further data regarding the effect of nicotine sulphate upon the borers when applied to the bark of infested trees are given in Table XII (p. 38).

CARBON DISULPHID.

Tests were made of the practicability of using a veterinary hypodermic syringe and needle for injecting carbon disulphid through the bark into the burrows of the borers. Considerable difficulty was encountered in inserting the needle, and especially in determining when the point of the needle was in proper position for the dis-

charge of the liquid. About 30 burrows were treated in one test and a subsequent examination showed that most of the borers had been killed by the resultant gas. The bark, however, was injured by the treatment. Where the liquid was injected into shallow burrows and came into contact with considerable areas of the inner bark more injury was done the tree than usually results from the direct work of a single borer.

Carbon disulphid can be injected with good results and with no apparent injury to the tree, into burrows that extend deep into the wood. Borers that penetrate beyond the reach of knife and wire can often be killed by discharging a little of the liquid into the open burrow and then plugging the opening with moist clay or some other substance. For injecting the liquid into such galleries, nothing is better than a medicine dropper with a curved point.

KEROSENE.

In September, 1914, 29 apple trees infested with roundheaded apple-tree borers were treated with kerosene, the liquid being applied liberally to the bark with a paintbrush over the regions where the borers were feeding. Four weeks later the trees were examined and 64 borers removed. Of these, 25 were dead and 39 alive. Severe injuries to the cambium and bark were beginning to show. A year later two of the treated trees were dead as a result of the oil application and others had large dead areas near the ground and around the base of the roots.

The conclusions derived from this test were that kerosene applied to the surface does not penetrate through the bark in sufficient quantities to kill all the borers and that its use in this way is dangerous to the health of the tree.

SODIUM ARSENATE WITH MISCIBLE-OIL CARRIER.

Late in the summer of 1918 a 10 per cent solution of sodium arsenate was mixed with a miscible-oil carrier and applied with a spray pump to the trunks of infested apple trees. The treatment was applied to 15 trees that averaged about 4 inches in diameter and contained borers of various ages and sizes. Early during the following spring the borers were removed from the trees, 28 specimens being obtained. Of these, 2 were dead and 26 alive and active. It could not be determined whether the two had died as a result of the treatment or from some other cause, and the treatment was considered of no practical value.

TESTS OF OTHER PENETRATING LIQUIDS.

In the summer and fall of 1917 a number of different penetrating liquids were used on infested apple trees in the experiment orchard

at Elkins. The liquids were applied with a paintbrush to the lower portion of the tree trunks as soon as it could be determined that all of the eggs of the season had hatched. The applications were made on August 16 to 17, and the trees examined for results 8 weeks later. The results of the treatments are set forth in Table XII. It should be borne in mind that all the borers considered in the table were newly hatched individuals that were feeding beneath only a thin layer of bark.

TABLE XII.—*Effect upon newly hatched roundheaded apple-tree borers of various liquids applied to the bark over the regions where they were feeding.*

Material used.	Number of trees treated.	Number of borers found—			Per cent of efficiency.
		Alive.	Dead.	Total.	
Nicotine sulphate, 1 part to 10 parts of water	60	26	20	46	43.5
Nicotine sulphate, undiluted	60	13	53	66	80.3
Raw linseed oil	60	22	16	38	42.1
Standard kerosene emulsion	60	28	28	56	50
10 per cent solution sodium arsenate, mixed with equal part of kerosene emulsion	60	15	31	46	67.4

It will be seen from Table XII that many borers may be killed by saturating the bark over where they are feeding with irritants and poisons of a penetrating nature, provided that the treatments are applied while the borers are still small and feeding in shallow burrows. All the materials used in the foregoing test killed a considerable number of borers, the undiluted nicotine sulphate giving best results. None gave complete control, and it is a question whether their use would be justified in orchard practice. Trees so treated would have to be gone over and wormed subsequently in order that entire freedom from borers might be assured.

SPRAYING WITH ARSENATES TO KILL THE ADULTS.

Feeding on the exposed surfaces of the apple and other host trees seems to be a general habit of the beetles. The bark of twigs and leaf stems and the tissues of the leaf are eaten. (Pl. IX, A, C.) Beetles were often observed manducating castings thrown out from the trees by larvæ, evidently for the moisture which the castings contained. The bark and leaf surface eaten away by one female totaled 6.9 square inches. This feeding habit suggests the use of poison sprays as a possible means of killing the beetles. In one small-scale experiment six newly emerged beetles were killed by applying a lead-arsenate spray to the foliage of a small apple tree over which they were caged. All died before the females were ready to oviposit.

In extreme cases of infestation it would probably be profitable to apply arsenical sprays to young apple orchards primarily for the

destruction of beetles of this species. Such sprays should be applied about 10 days after the blossoms have disappeared from apple trees and should consist of 4 or 5 pounds of lead arsenate paste to 50 gallons of water, or of the equivalent of this strength prepared with some other insecticidal poison. When trees reach a bearing age, the so-called first codling-moth spray will serve also to kill the beetles of the roundheaded apple-tree borer.

SUMMARY.

The roundheaded apple-tree borer is a native American insect that has been recognized as a serious pest of the apple, pear, and quince since the early days of orcharding in this country.

It occurs in the United States and Canada over most of the apple-growing region east of the Rocky Mountains.

In addition to the cultivated fruits named above, it breeds also in such wild trees as wild crab, hawthorn, mountain ash, and service. These native trees growing in woods or neglected fields often serve as centers in which the adults develop and from which they fly to near-by orchards to deposit their eggs.

In the woods and in orchards the insect is inclined to colonize, families or communities living in the trees of somewhat restricted localities. Often infestation in an orchard or in native woods will be confined for years to rather definite areas or spots. This habit is due largely to the inclination of the adult female to deposit her eggs near the place where she developed.

The common belief that borers of this species prefer to attack trees planted in new ground, in hilly situations, or in certain kinds of soils probably arises from the fact that such situations favor a more abundant growth of the native host trees of the insect. In these wild trees many adults develop and cause serious infestation of adjacent orchards.

About 95 per cent of the eggs from which the borers hatch are deposited in the bark within a few inches of the ground. The incubation period is about 16 days. The borers feed in the bark and wood for from one to four years and finally pupate at the end of an ascending gallery which extends up the trunk from a few inches to approximately 2 feet above the ground.

The burrows made in the bark and wood are broad and irregular in form. Often several borers work close together, as many as 25 or 30 having been found in a single tree. Infested trees become sickly in appearance. They are inclined to bloom freely and set heavy crops of fruit, but often die in an attempt to bring the crop to maturity. Young trees suffer most but trees of all ages are attacked. Trees of an orchard standing near woods are more likely to be injured by borers than those more distant from the woods.

In depositing her eggs the female beetle makes a slit in the bark with her mandibles and then inserts her ovipositor and places the egg between the bark and wood or between layers of the bark. About 9 or 10 minutes are required for the deposition of a single egg. Usually from 2 to 5 eggs are laid at a time. Probably all eggs are deposited by day, and the female in ovipositing shows a slight preference for the sunny or exposed side of the trunk, 65 per cent of the eggs being found in one case on the exposed side of the tree. In the latitude of West Virginia, the average number of eggs deposited by a single female is apparently from 20 to 30. Oviposition in a given locality extends over a period of from 50 to 60 days.

The larvæ begin to feed immediately after hatching and usually grow rapidly the first season. Feeding is continued until cold weather and is resumed again in the spring shortly before the blossoming time of the apple. The larva may spend from one to four years in the tree, this stage being of longer duration in the North than in the South. At French Creek, W. Va., 85 per cent of the larvæ remained in the trees two years before pupation, and 12 per cent three years. At Winthrop, Me., 25 per cent remained in the tree three years and 75 per cent four years.

The pupal stage lasts about 20 days and the period is about coincident with the blossoming time of apple. After changing to beetles the insects remain in the pupal chamber for from 5 to 10 days and then gnaw a circular hole through the bark at the upper end of the chamber and escape. The beetles appear in the South earlier than in the North. Between Demorest, Ga., and Munising, Mich., there was a difference of 75 days in the dates of the emergence of the first beetles. At French Creek, W. Va., beetles issued from the wood during two different years over a period of 30 days. Other years the period was shorter. May 12 was the earliest date for the appearance of a beetle in any year at French Creek, and June 23 was the latest date. A few beetles lived 60 days after issuing.

Pairing may take place at once or may be delayed 10 days after emergence. Eggs are laid soon after pairing. In an apple orchard containing 310 King, 341 Grimes, and 341 York Imperial trees, the Grimes were most severely attacked in four out of five years, nearly 50 per cent of all the eggs being laid in Grimes trees. This could be accounted for in no other way than that the borers showed a preference for this variety.

Experiments showed that the female beetles during oviposition are capable of flying to a considerable distance, but that they prefer to place their eggs in trees near the place where they themselves have developed. By preventing the development of adults in the orchard trees and in other trees growing within from 300 to 600 feet of the orchard, subsequent infestation was reduced 73.6 per cent.

The borers have few insect enemies, but woodpeckers play an important part in holding them in check. The downy woodpecker was observed removing borers from trees.

No easier and cheaper way of controlling borers was found than the old method of worming trees. The worming should be done as soon as possible after the last eggs of the season have hatched, and should be repeated in the spring following the blossoming time of apple trees. Worming can be done most effectively by two men working together on opposite sides of the tree. In this practice emphasis is placed on the importance of removing all breeding centers within or adjacent to the orchard.

Paints and various other kinds of tree protectors were used to prevent the adult females from ovipositing in the bark. Nothing of this nature was found that surpassed common white-lead paint in cheapness, ease of application, and effectiveness in controlling the borers. Young apple trees painted once annually for from four to six years showed no injury and the treatment gave a control efficiency of 74.3 per cent.

Various attempts to kill borers were made by applying to the bark of infested trees penetrating liquids of a poisonous or irritating nature. Nicotine sulphate, kerosene, kerosene emulsion, sodium arsenate in a miscible-oil carrier, and linseed oil were among the materials tested. None of these was effective on large borers that had penetrated deep into the tree, but most of them killed a considerable percentage of young borers that were still feeding in shallow burrows.

The beetles feed rather freely upon leaves and the bark of twigs. Tests made indicate that it is possible to kill the beetles by spraying with arsenicals. Sprays for this purpose should be applied to young orchards within 10 days after apple blossoms have disappeared. In bearing orchards what is known as the first codling-moth spray will be effective also against the adults of the roundheaded apple-tree borer.

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